Issued July 21, 1910.

U. S. DEPARTMENT OF AGRICULTURE,

OFFICE OF EXPERIMENT STATIONS—BULLETIN 218.

A. C. TRUE, Director.

IRRIGATION IN COLORADO.

BY

C. W. BEACH AND P. J. PRESTON,
Former Deputy State Engineers, Colorado.

PREPARED UNDER THE DIRECTION OF

SAMUEL FORTIER,
Chief of Irrigation Investigations.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1910.


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OFFICE OF EXPERIMENT STATIONS.

A. C. True, Director.
E. W. Allen, Assistant Director.

IRRIGATION INVESTIGATIONS.

Samuel Fortier, Chief.
R. P. Teele, Assistant Chief.

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C. E. Tait, Irrigation Engineer, in charge of work in Imperial Valley and Arizona.
S. O. Jayne, Irrigation Manager, in charge of work in Washington.
Frank Adams, Expert, in charge of work in California.
W. W. McLaughlin, Irrigation Engineer, in charge of work in Utah.
P. E. Fuller, Irrigation Engineer, in charge of power investigations.
W. L. Rockwell, Irrigation Manager, in charge of work in Texas.
D. H. Bark, Irrigation Engineer, in charge of work in Idaho.
Milo B. Williams, Irrigation Engineer, in charge of work in humid sections.
V. M. Cone, Irrigation Engineer.
C. G. Haskell, Irrigation Engineer, in charge of rice investigations.
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IRRIGATION FARMERS.

John H. Gordon, R. G. Hemphill, W. H. Lauck, R. E. Mahoney, and John Krall, Jr.

LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF EXPERIMENT STATIONS,
Washington, D. C., March 21, 1910.

SIR: I have the honor to transmit herewith a report on irrigation in Colorado, prepared under the direction of Samuel Fortier, chief of irrigation investigations, by C. W. Beach and P. J. Preston, former deputy state engineers of Colorado. This is one of the series of reports on irrigation in the several arid States and Territories, prepared by the irrigation investigations of this Office for the purpose of supplying to prospective settlers in the arid region the information needed by them. It is recommended that it be published as a bulletin of this Office.

Respectfully,

A. C. TRUE,
Director.

Hon. JAMES WILSON,
Secretary of Agriculture.

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GENERAL DESCRIPTION.

Colorado lies between the thirty-seventh and forty-first degrees of north latitude and the twenty-fifth and thirty-second degrees of longitude west of Washington, being 280 miles from north to south and approximately 380 miles from east to west, and contains 103,948 square miles, or 66,526,720 acres. The eastern portion of the State is a continuation of the broad, flat prairies of western Kansas and Nebraska and varies in elevation from 3,400 to 5,300 feet. The Rocky Mountains extend north and south through the central portion of the State. There are 41 peaks in the State which rise to an elevation of 14,000 feet or more. Just west of the eastern range lie four mountain valleys known as North Park, Middle Park, South Park, and San Luis Valley. These valleys are situated at moderate elevations and, with the exception of the San Luis Valley, are surrounded by mountain ranges. The ranges west of these valleys form the Continental Divide. Scattered over what is known as the western slope are many very fertile valleys, which are especially adapted to fruit growing.

The headwaters of many of the large rivers of the West are in Colorado. The North Platte River rises in North Park; the South Platte River, in the mountains west of Denver; the Arkansas River, near the mining town of Leadville; the Rio Grande, in the San Luis Valley; and many of the largest tributaries of the Colorado River, in the western part of the State. (Pl. I.)

Colorado possesses a great variety of physical and climatic conditions, varying from those of the highest mountain regions, where vegetation ceases to flourish, to those of valleys where the more tender temperate-zone fruits can be raised. Various sections of the State are adapted especially to certain crops, owing to favorable climatic and soil conditions. A settler must first decide what kind of farming or stock raising he desires to engage in and then locate in the section

adapted to that particular industry. Both the plains and the mountains of the State are adapted to cattle and sheep raising. Alfalfa and cereals grow in all the irrigated portions. Some sections grow potatoes successfully, some cantaloups, some peaches and apples, while the high mountain valleys grow field peas and timothy quite successfully. Sugar beets can be grown with profit in practically all of the agricultural sections of the State.

In 1900 Colorado had a population of 500,000. Since that date the population of all the agricultural sections has increased greatly, due largely to success in growing sugar beets.

The surface of the State is divided into 66,341,120 acres of land and 185,600 acres of water. Of the total area, 15,554,115 acres are in National Forest. The National Forests as a rule are composed of the rough mountainous portions of the State, land which can not be used for successful agriculture and which at some time has grown pine trees. Much of it suffered from fires in the days before the forests were patrolled. The National Forests are as follows:

National Forests, address of supervisor, and area.

Name of forest.	Address of supervisor.	Area.	Name of forest.	Address of supervisor.	Area.
		Acres.			*Acres.*
Arapaho	Fraser	796,815	Montezuma	Mancos	1,175,811
Battlement	Collbran	742,440	Pike	Denver	1,457,524
Cochetopa	Saguache	932,890	Rio Grande	Monte Vista	1,262,158
Gunnison	Gunnison	945,350	Routt	Steamboat Springs	1,049,686
Hayden	Encampment, Wyo.	84,000	San Isabel	Westcliffe	635,992
			San Juan	Durango	1,460,880
Holy Cross	Glenwood Springs.	595,840	Sopris	Aspen	655,360
La Sal	Moab, Utah	29,502	Uncompahgre	Delta	921,243
Leadville	Leadville	1,184,730	White River	Meeker	964,114
Medicine Bow	Fort Collins	659,780			
			Total forest area June 1, 1910		15,554,115

Nearly 25,000,000 acres are still unappropriated and unreserved, much of which is open to entry under the United States land laws. During the year 1907 2,483,666.69 acres of public land were disposed of in various ways. The lands can be classified as follows:

Classification of lands.

Class.	Acres.	Class.	Acres.
Arable	22,400,000	Under canals	2,894,000
Mountainous	43,755,520	Probable limit of irrigated land	4,500,000
National forests	15,554,115		

The following table, taken from the fourteenth biennial report of the state engineer, shows the irrigable area, acreage of the different crops grown, and the number of acres irrigated in 1908:

Irrigable area, acreage of different crops, and acres irrigated in 1908.

Irrigation division.	Length of main ditch.	Water used by canals for season.	Area that can be irrigated.	Alfalfa.	Natural grasses.	Cereals.
	Miles.	*Acre-feet.*	*Acres.*	*Acres.*	*Acres.*	*Acres.*
No. 1	3,137	1,150,363	1,222,869	222,725	175,348	301,508
No. 2	2,461	618,305	581,229	176,576	94,782	87,576
No. 3	1,425	....	624,697	13,661	190,298	142,394
No. 4[a]	....	....	[b] 250,000	41,919	7,064	23,149
No. 5[c]	....	....	[b] 200,000	32,660	32,787	22,226
Total	....	....	2,878,795	487,541	500,279	576,853

Irrigation division.	Orchards.	Market gardens.	Potatoes.	Sugar beets.	Other crops.	Field peas.	Total irrigated.
	Acres.	*Acres.*	*Acres.*	*Acres.*	*Acres.*	*Acres.*	*Acres.*
No. 1	15,744	21,869	47,129	93,720	46,061	....	924,104
No. 2	16,139	5,565	672	51,895	33,152	....	466,357
No. 3	43	275	7,534	10	....	85,024	439,239
No. 4[a]	11,092	557	4,455	1,556	350	....	90,142
No. 5[c]	2,458	227	4,247	1,095	6,438	267	102,405
Total	45,476	28,493	64,037	148,276	86,001	85,291	2,022,247

[a] Six districts out of 17 reported.
[b] Estimated for the entire irrigation division.
[c] Nine districts out of 17 reported.

The total area irrigated, including districts not reported to the state engineer, is about 2,000,000 acres, and the total under canal which it is possible to irrigate, about 2,900,000 acres. There is 1,000,000 acres of uncultivated land which could be irrigated lying in the newer sections of the State. Of the total area irrigated 832,130 acres are watered from the South Platte River and its tributaries, 466,357 acres from the Arkansas River and its tributaries, 439,239 acres from the Rio Grande and its tributaries, and the remainder is scattered throughout the State in various smaller valleys.

Farming by irrigation is of such a nature that the best returns are to be secured by individual effort of the small farmer. The tendency is toward smaller farms and more intense cultivation. The average size of the irrigated farm in 1902 was 88.6 acres; to-day it is less than 80 acres.

TRANSPORTATION FACILITIES.

Denver is the railroad center of the State, and roads radiate from it in nearly all directions. The Denver and Rio Grande system runs south 120 miles to Pueblo, up the Arkansas River Valley to Leadville, crosses the Continental Divide at Tennessee Pass at an elevation of 10,000 feet, continues westward down the Eagle and Grand rivers, and leaves the State west of Grand Junction, thus affording direct connections with Salt Lake City and the Pacific coast. At Denver and at Pueblo it connects with the Chicago, Burlington and Quincy,

the Union Pacific, the Rock Island, the Atchison, Topeka and Santa Fe, the Missouri Pacific, and the Colorado and Southern, furnishing transportation facilities to points east and south. The Rio Grande system, with its many branches into the Trinidad coal fields and the Gunnison and Uncompahgre valleys, is one of the most important systems in the State.

The northeastern portion of the State is served by the Union Pacific and the Colorado and Southern, both having direct connections with tidewater. The southeastern part of the State is served by the Santa Fe, the Colorado and Southern, the Denver and Rio Grande, and the Missouri Pacific. The Santa Fe system gives transportation facilities to California, Texas, the South and the East, and the Rock Island and Burlington, with Omaha, Kansas City, and Chicago. The northwestern portion of the State is at present the only part without good transportation facilities, but the Denver, Northwestern and Pacific Railroad Company, which is now building westward from Denver into Routt County, will in the near future furnish an outlet for the coal fields and stock interests of this section.

The report of the Colorado state board of equalization gives 3,697.13 miles of standard-gauge railroad track, of which 42.41 miles is double-tracked. There are 1,439.15 miles of narrow-gauge track, with the necessary side tracks, making a total of 5,136.28 miles of main track in the State. The assessed valuation of the railroad property of the State in 1907 was $48,570,919.

TAXATION.

The total assessed value of the State in 1907 was $366,988,141, the assessed valuation being approximately one-third the full value. The state levy is limited to 4 mills, and the amount raised in 1907 was $1,467,952, which, together with the fees of the various departments and the inheritance tax, made the total income of the State $2,172,791.

PRINCIPAL INDUSTRIES.

The principal industries of the State are agriculture, mining, smelting, and refining.

Agriculture is confined chiefly to narrow strips along the rivers and their tributaries, but extends well out upon the plains, along the mountain valleys, and in the parks. Some agriculture is practiced without the aid of irrigation on the broad plains away from the main streams, and in some favorably located areas in the mountains.

Fruit raising is carried on mostly in the narrow valleys lying within or close to the mountainous areas.

Stock raising is engaged in in nearly all portions of the State. Within the past fifteen years the feeding of cattle, lambs, and hogs has developed into a very important industry in many of the irrigated districts.

Metalliferous mining is well distributed over the mountainous sections of the State. Coal mining is carried on along the eastern base of the mountains, in the southwestern and west central sections of the State.

CLIMATE.

The plains region of Colorado has an essentially arid climate. The winds in crossing the high mountains to the west are cooled and robbed of their moisture and upon descending again are warmed and their moisture-carrying capacity greatly increased. This gives rise to a climate characterized by the dryness and pureness of the air, the cloudless sky, and the cool nights. The summer days are clear with few exceptions, and although quite warm the heat is not oppressive as in more humid regions. Sunstrokes and prostrations from heat are almost unknown. In these high arid regions it is noticeable that no matter how bright the day and how great the heat of the sun, it is always cool and comfortable in the shade, and that as soon as the sun sets it becomes much cooler.

The climate in the fall is mild, with little wind, the weather becoming gradually cooler until about December 1, when there is a sudden change and winter sets in. The early part of winter is accompanied by few storms; frequently no rough weather occurs until February. The winters are generally short, sometimes being so mild as to interfere little with farm work. The thermometer rarely goes to 20° below zero at any place in the State except in the higher mountain regions. During occasional periods, however, even in the plains region, the cold is quite severe, but these periods are of short duration, are soon followed by mild weather, and lose much of their severity on account of the dry atmosphere. Light snowfalls are a common occurrence in the plains region, but the snow rarely remains on the ground more than a day or two at a time. Cattle, horses, and sheep can live through the winter upon the open prairie with no other feed than the native buffalo grass, but do much better if fed during the stormy periods. Cattle and sheep are fattened for the market during the winter months, having no other protection than windbreaks of trees or alfalfa stacks. High up in the mountains the winters are cold and vegetation scant, but it is not necessary for people to live in those regions. March is usually a windy month, April and May have showers, and the months of June, July, and August comprise the greater part of the growing season. Many of the mountain valleys have a climate adapted especially to fruit growing, being protected

from late frosts in the spring, from sudden changes of temperature, and from high winds when the trees are heavily laden with fruit. Fogs are rare. Brisk winds are common only in the plains regions, where they meet with practically no resistance, but even here cyclones are unknown. The abundance of sunshine, amounting to about 65 per cent of the days, imparts a cheerfulness to the people and is one of the great advantages of farming in an arid region, providing fine weather in which to cultivate and harvest crops.

Below are given tables compiled from the reports of the United States Weather Bureau, showing the mean monthly and annual precipitations, the mean monthly temperature, the percentage of clear days, the hourly velocity of the wind, the altitude, average dates of the last killing frost in the spring and the first in the fall, and the average length of the growing season for the various stations throughout the State:

Mean annual and mean monthly precipitation and percentages of annual precipitation for stations throughout Colorado.[a]

Location.	Mean annual precipitation.	January.		February.		March.		April.		May.		June.	
PLAINS STATIONS.	*In.*	*In.*	*P. ct.*	*In.*	*P. ct.*	*In.*	*P. ct.*	*In.*	*P. ct.*	*In.*	*P. ct.*	*In.*	*P. ct.*
Denver	14.02	0.42	3.00	0.49	3.50	1.00	7.13	2.17	15.58	2.54	18.12	1.47	10.49
Fort Collins	14.91	.50	3.35	.57	3.82	1.01	6.77	2.32	15.56	2.93	19.65	1.59	10.66
Colorado Springs	14.41	.18	1.25	.30	2.08	.77	5.34	1.60	11.10	2.44	16.93	1.99	13.81
Pueblo	11.95	.35	2.93	.47	3.93	.86	7.20	1.43	11.96	1.68	14.06	1.47	12.31
Trinidad[b]	17.17	.37	2.16	.84	4.89	.65	3.79	1.73	10.07	1.89	11.01	2.88	16.78
Rockyford (near)	13.10	.34	2.60	.37	2.82	.76	5.80	1.68	12.82	2.00	15.27	1.38	10.53
Canyon[b]	12.37	.43	3.47	.63	5.09	.77	6.22	1.71	13.82	1.96	15.84	1.01	8.16
Mean	14.00	.38	2.71	.52	3.71	.78	5.57	1.81	12.93	2.23	15.92	1.66	11.86
MOUNTAIN AND PARK STATIONS.													
Salida	11.47	.36	3.14	.55	4.79	.86	7.50	2.12	18.48	.80	6.97	1.03	8.98
Breckenridge	25.76	1.84	7.14	2.94	11.41	3.35	13.00	3.04	11.80	2.26	8.77	1.11	4.31
Collbran	14.59	.98	6.72	1.38	9.46	1.91	13.09	1.48	10.14	1.45	9.94	.60	4.11
Durango	16.66	1.28	7.69	1.39	8.35	1.46	8.77	1.14	6.85	1.14	6.85	.78	4.68
Delta	[c]7.89	[b].52	6.59	.59	7.48	.71	9.00	.51	6.46	.68	8.62	.29	3.68
Grand Junction	8.30	.49	5.91	.63	7.59	.71	8.56	.76	9.17	.92	11.09	.40	4.82
Mancos	17.29	1.19	6.88	1.40	8.10	2.41	13.94	2.30	13.30	1.65	9.54	.88	5.14
Meeker	15.91	1.06	6.67	1.23	7.74	1.84	11.58	1.57	9.87	1.37	8.62	.96	6.03
Montrose[d]	9.54	.72	7.55	.72	7.55	.83	8.70	.92	9.65	.75	7.86	.39	4.09
Saguache	7.21	.20	2.77	.25	3.47	.20	2.77	.49	6.80	.75	10.40	.83	11.51
Mean	13.45	.87	6.47	1.11	8.25	1.44	10.71	1.42	10.56	1.14	8.48	.71	5.28

Location.	July.		August.		September.		October.		November.		December.	
PLAINS STATIONS.	*In.*	*P. ct.*	*In.*	*P. ct.*	*In.*	*P. ct.*	*In.*	*P. ct.*	*In.*	*P. ct.*	*In.*	*P. ct.*
Denver	1.62	11.55	1.34	9.56	0.89	6.35	0.96	6.85	0.52	3.71	0.60	4.28
Fort Collins	1.85	12.41	1.14	7.65	1.23	8.25	1.03	6.91	.41	2.75	.33	2.21
Colorado Springs	2.85	19.78	2.05	14.22	1.07	7.42	.65	4.51	.26	1.80	.25	1.64
Pueblo	1.97	16.49	1.57	13.14	.62	5.19	.70	5.86	.37	3.10	.46	3.85
Trinidad[b]	2.23	12.98	2.43	14.15	1.51	8.79	1.16	6.79	.82	4.76	.66	3.88
Rockyford (near)	2.72	20.76	1.31	10.00	.85	6.49	.85	6.49	.36	2.75	.48	3.66
Canyon[b]	1.94	15.68	1.83	14.79	.56	4.52	.78	6.30	.30	2.42	.45	3.64
Mean	2.20	15.71	1.74	12.43	.93	6.64	.88	6.28	.43	3.07	.47	3.36

[a] Annual summary, 1907.
[b] Annual summary, 1906.
[c] January, 1906, and others 1907.
[d] Fourteen years between 1885 and 1908.

Mean annual and mean monthly precipitation and percentages of annual precipitation for stations throughout Colorado—Continued.

Location.	July.		August.		September.		October.		November.		December.	
MOUNTAIN AND PARK STATIONS.	*In.*	*P. ct.*	*In.*	*P. ct.*	*In.*	*P. ct.*	*In.*	*P. ct.*	*In.*	*P. ct.*	*In.*	*P. ct.*
Salida	1.53	13.37	1.16	10.11	0.98	8.54	1.09	9.50	0.46	4.01	0.53	4.62
Breckenridge	2.16	8.39	2.17	8.42	1.22	4.74	1.41	5.47	1.93	7.49	2.33	9.04
Collbran	1.20	8.23	1.24	8.50	1.36	9.32	1.00	6.85	.90	6.17	1.09	7.47
Durango	1.55	9.31	1.79	10.74	1.85	11.11	1.75	10.50	1.13	6.79	1.40	8.40
Delta	.80	10.14	1.35	17.11	.84	10.64	.55	6.97	.51	6.46	.54	6.84
Grand Junction	.50	6.03	1.04	12.53	.95	11.45	.91	10.97	.55	6.63	.44	5.30
Mancos	1.11	6.42	1.74	10.06	1.55	8.96	.81	4.68	1.35	7.81	.90	5.20
Meeker	1.48	9.31	1.32	8.31	1.72	10.82	1.29	8.12	.95	5.98	1.12	7.05
Montrose [a]	.84	8.81	1.33	13.95	.92	9.65	.86	9.02	.55	5.77	.71	7.44
Saguache	1.48	20.53	1.26	17.48	.64	8.87	.71	9.84	.21	2.91	.19	2.64
Mean	1.27	9.44	1.43	10.31	1.21	9.00	1.06	7.88	.87	6.47	.92	6.84

[a] Fourteen years between 1885 and 1908.

Monthly mean temperature at stations throughout Colorado.

Location.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
PLAINS STATIONS.	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*
Denver	29.1	31.1	38.7	47.7	56.7	66.4	71.8	70.4	62.7	51.0	39.2	32.2
Fort Collins	26.3	26.1	35.5	45.8	55.0	64.0	68.5	67.7	59.5	48.1	35.4	29.6
Colorado Springs	27.5	29.3	36.6	44.9	54.5	63.6	68.0	67.0	59.3	48.3	37.4	30.9
Pueblo	29.1	31.8	40.6	50.5	59.5	69.0	74.2	72.1	64.4	52.3	39.3	31.7
Trinidad [a]	34.1	34.9	42.8	49.8	59.2	66.3	71.2	70.2	63.1	53.0	43.4	35.1
Rockyford (near)	28.9	30.8	40.2	51.9	60.8	70.2	74.3	74.0	65.2	52.7	39.7	31.3
Canyon	33.7	34.1	41.9	51.6	59.6	69.0	73.0	72.3	64.6	53.0	42.0	37.7
MOUNTAIN AND PARK STATIONS.												
Salida	27.7	30.5	36.0	44.0	52.9	60.7	64.9	64.9	57.4	47.1	37.3	27.4
Breckenridge	15.4	15.8	22.5	29.8	39.2	48.3	53.3	53.5	46.6	36.2	26.2	17.4
Collbran	22.0	28.3	37.0	47.1	54.8	63.4	68.8	68.5	59.6	47.9	36.8	24.6
Durango	24.5	29.9	37.5	46.4	55.0	62.7	68.7	66.3	58.2	48.9	37.2	28.3
Delta	......	30.1	40.6	50.9	59.5	68.1	74.1	72.3	62.5	49.6	36.9	25.4
Grand Junction	24.7	31.5	43.5	53.2	61.6	72.6	79.2	76.1	66.4	53.3	39.9	28.2
Mancos	26.3	30.0	37.2	44.4	52.0	60.6	66.0	64.9	57.6	47.4	37.5	27.4
Meeker	19.6	23.3	33.4	44.0	52.4	60.2	65.9	64.5	55.6	43.8	33.0	19.9
Montrose [b]	23.2	31.5	39.7	47.5	55.0	63.9	70.2	67.5	60.5	48.4	35.7	27.6
Saguache	18.5	22.4	33.7	43.3	51.6	59.5	64.2	62.6	55.2	45.2	32.9	20.1

[a] Annual summary, 1906. [b] Fourteen years between 1885 and 1908.

Percentage of possible sunshine, by months, for 1903–1907 at stations throughout Colorado.

Location.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Denver	64	67	58	62	56	63	67	68	68	73	66	67	65
Pueblo	75	78	71	70	73	71	74	74	78	79	80	82	75
Durango [a]	68	73	66	67	74	87	81	81	83	85	76	73	76
Grand Junction	56	61	53	65	65	75	73	70	74	81	72	65	67
Cheyenne, Wyo	62	65	56	58	53	63	65	68	67	73	68	65	64

[a] 1903–1905.

Average hourly wind velocity (in miles), by months, for 1903–1907 at stations throughout Colorado.

Location.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Denver	8.0	8.3	8.2	8.7	7.9	7.4	7.0	6.8	7.2	7.4	7.2	8.0	7.7
Pueblo	6.9	7.1	7.8	8.9	8.0	6.9	6.7	6.3	6.4	6.3	5.8	6.4	7.0
Durango [a]	4.8	5.1	5.5	6.4	6.6	6.5	5.7	5.3	5.6	5.7	5.3	5.1	5.7
Grand Junction	3.4	4.0	5.7	6.1	5.9	6.0	5.5	5.3	5.0	4.2	3.8	3.5	4.9
Cheyenne, Wyo	12.5	11.7	11.2	11.2	10.4	9.8	8.3	7.9	8.7	9.5	9.9	11.9	10.3

[a] 1903–1905.

Altitude, average dates of last killing frost in the spring and the first in the fall, and average length of growing season throughout Colorado for the years 1902–1908.[a]

Station.	Altitude.	Average last killing frost in spring.	Average first killing frost in fall.	Average length growing season.
PLAINS SECTION.	*Feet.*			*Days.*
Denver	5,291	Apr. 27	Oct. 5	161
Fort Collins	4,994	[b]May 11	Sept. 19	131
Colorado Springs	6,072	May 6	Sept. 26	143
Pueblo	4,685	Apr. 29	Oct. 8	162
Trinidad	5,963	May 2	[c]Oct. 8	159
Rockyford	4,177	May 1	Sept. 26	148
Canyon	5,363	May 6	Oct. 4	151
PARK AND MOUNTAINOUS SECTION.				
Salida	7,038	June 8	Sept. 18	102
Breckenridge	9,524	([d])	([d])	....
Collbran	6,000	May 29	Sept. 24	118
Durango	6,551	May 25	Sept. 23	121
Delta	4,980	[c]May 9	[c]Sept. 25	139
Grand Junction	4,608	Apr. 10	Oct. 23	196
Mancos	6,996	June 14	Sept. 19	97
Meeker	6,182	[e]June 22	[e]Sept. 6	76
Montrose	5,819	[c]June 9	[c]Sept. 28	111
Saguache	7,740	[b]June 8	[b]Sept. 23	107

[a] Minimum temperature of 32° F. or lower.
[b] One year missing.
[c] Two years missing.
[d] Generally every month of the year.
[e] Every month in 1905.

SOIL.

The soils of the plains region of Colorado can be divided into two classes, upland and river bottom.

The upland soils are of residual origin, being formed by the disintegration of rocks upon which they rest. As a rule, they show no stratification. The mineral constituents are very similar to the parent rock; in some instances, especially in the case of fine, sandy loams, the soil extends to bed rock without marked variations in texture. These soils are the easiest to till and irrigate and the most productive.

The soils of the mountain valleys were formed by the disintegration of the adjacent rock which in some places is of volcanic origin and in others of sedimentary origin. These soils necessarily vary greatly in character. Those formed by the disintegration of granite or of red or light-colored sandstone are generally of a sandy-loam character, while those formed by the disintegration of the limestones and shales are heavy and are classed as adobes.

The river bottoms are true alluvial soils, having been deposited by the action of the water. They are more or less stratified, and the mineral particles and rock fragments composing them are varied in character. It is estimated that 75 per cent of the soils of Colorado are sandy loams. These are easy of cultivation, scouring on the plows nicely, and are very fertile when water is applied. Being of a coarser texture they retain more moisture than the heavier adobe

soils and by a judicious rotation of crops can be brought to a high state of productivity.

Aside from the soils of alluvial origin, Colorado soils contain much of the original mineral in the parent rock. They are rarely saturated to any depth and the soluble parts of the virgin soil have not been carried away by the leaching action of the water during the past ages. This fact is shown by a comparison of analyses of the soils of the different States in the humid region with those of the Colorado soils.

Chemical analyses of Colorado soils as compared with those of humid regions.[a]

Constituents.	Colorado.	Average for humid region.	Constituents.	Colorado.	Average for humid region.
	Per cent.	*Per cent.*		*Per cent.*	*Per cent.*
Insoluble residue	77.70	84.17	Alumina	4.98	3.66
Soluble silica	7.10	4.04	Phosphoric acid	.23	.12
Sum of insoluble residue and soluble silica	84.80	88.21	Sulphuric acid	.08	.05
			Water and organic matter	3.57	4.40
Potash	.44	.21	Hydroscopic moisture	2.31	....
Soda	.44	.14	Humus	....	1.22
Lime	1.43	.13	Nitrogen in humus	....	....
Magnesia	.81	.29	Nitrogen in soil	.03	....
Br. oxid manganese	....	.13			
Peroxid of iron	3.82	3.88	Number analyzed	16	696

[a] Soils, by E. W. Hilgard, p. 377.

The Bureau of Soils of the United States Department of Agriculture has made some extended soil surveys of the principal agricultural sections of the State. A number of different kinds of sandy loam are found, as shown by the mechanical analyses in the following table:

Mechanical analyses of Colorado soils.

Kind of soil.	Fine gravel, 2-1 mm.	Coarse sand, gravel, 1-0.5 mm.	Medium sand, 0.5-0.25 mm.	Fine sand, 0.25-0.1 mm.	Very fine sand, 0.1-0.05 mm.	Silt, 0.05-0.005 mm.	Clay, 0.005-0 mm.	Organic matter.
Colorado sandy loam	0.70	2.80	1.80	19.60	34.90	28.60	10.80	....
Fort Collins loam	.90	2.90	3.60	17.30	22.90	31.50	20.80	....
San Luis sandy loam	6.46	12.44	5.70	16.04	21.40	25.48	12.16	0.80
Rio Grande sandy loam	1.70	4.39	3.20	15.52	20.17	34.12	20.78	1.08
Fresno fine sandy loam	.08	1.10	2.16	8.26	19.02	56.46	12.78	.91

Alkali soils occur to some extent in Colorado as in all regions where the rainfall is insufficient to leach out the soluble salts that always form in the weathering of the rock powder of which residual soils are composed. Where the rainfall is abundant these soluble salts are dissolved by the water passing through the soil and are carried eventually through the rivers to the sea. The alkali of Colorado soils consists essentially of sodium sulphate, magnesium sulphate, and calcium sulphate,[a] with some sodium chlorid (common salt) and

[a] Colorado Sta. Bul. 65.

sodium carbonate. Recent investigations by the Colorado Experiment Station show that spots containing an excess of nitrates are of frequent occurrence in different parts of the State.

Water applied by irrigation to new soils will dissolve the soluble alkali salts, and if drainage conditions are good and the water reaches a natural watercourse the salts will be carried away; but if the drainage is defective, the alkali salts will accumulate until the soil is so strongly impregnated that plant life will cease. Thus soils which have good drainage are never troubled with alkali and those tracts upon which alkali appears can be reclaimed by draining, either with tile or an open ditch. Many low places once swampy and impregnated with alkali have been reclaimed already and have become fine farming land.

WATER RESOURCES.

In a general way it can be said that all of the waters of the South Platte, Arkansas, and Rio Grande rivers can be appropriated for irrigation. The limit of irrigation along these streams is the quantity of water they can deliver, as the area along them is greater than the streams can supply. An average of 1,623,000 acre-feet of water escapes through these streams each year. If it were possible to divert all this water either into canals or reservoirs it would reclaim 649,200 acres of land, allowing 2.5 acre-feet of water per acre. This quantity applied to the land would necessarily increase the seepage return and make still more water available for reclamation. Probably 700,000 acres more than is being supplied at present can be reclaimed on the water sheds of these streams. No less than five projects are under consideration for diverting the waters of other streams from the western to the eastern slopes of the mountains into the watersheds of these three streams by means of ditches and tunnels through the mountains. Some of these projects have assumed quite large proportions and will be constructed at some future time. To what extent they will reclaim land it is impossible to state, as not enough exploration work has been done to justify an estimate. The streams in the western part of the State run through narrow valleys and the areas which it is possible to irrigate from them are quite limited.

STREAM MEASUREMENTS.

Below is given a statement of the amount of water which escapes from the State each year, expressed in acre-feet. These figures were obtained from reports upon stream measurements made by the United States Geological Survey and the state engineers.

Amount of water escaping from streams of Colorado each year.

Stream.	Acre-feet.	Stream.	Acre-feet.
South Platte River at Nebraska line....	406,000	White River at Rangeley..............	389,300
Arkansas River at Kansas line..........	681,000	Yampa River at Maybell..............	919,400
Rio Grande at New Mexico line.........	536,000	Gunnison River at Iola................	2,062,000
Laramie River at Wyoming line.........	120,000	San Juan River at New Mexico line....	279,300
North Platte River at Wyoming line....	925,000		
Animas River near Durango............	859,000	Total..............................	10,555,000
Grand River at Palisades..............	3,378,000		

Aside from the South Platte, Arkansas, and Rio Grande, and possibly the Laramie, the figures indicate nothing regarding irrigation except that there is an abundance of water for the land which it is possible to irrigate, and that there is a large quantity of water available for power purposes. Much of the water of the Laramie River can be diverted across the mountains to the South Platte drainage, there to be used upon lands which will grow higher-priced crops than are grown in the Laramie River basin.

SOUTH PLATTE RIVER.

The headwaters of this stream have their sources in the high mountain peaks surrounding the basin known as South Park. The average elevation of the valley is 8,000 feet above sea level, while the peaks attain an elevation of 13,000 feet and are in the region of perpetual snow. The moisture-laden atmosphere passing across these high mountains becomes chilled to a point where it can not retain the moisture brought from the plains below and deposits it as snow through the fall, winter, and spring months. This remains until melted by the summer sun and acts as a reservoir, forming the source of supply of all the perennial mountain streams.

The South Platte River emerges from the mountains at Platte Canyon, 20 miles southwest of Denver, and becomes a plains stream. In the mountains the channel of the stream is narrow and the fall rapid; on the plains the channel is broad and sandy and the fall light. The drainage area above the mouth of the canyon is 2,600 square miles. From the mouth of the canyon the river flows in a general northerly direction, diverging slightly to the east, and picking up on its course the waters of Bear, Clear, Boulder, South Boulder, St. Vrain, Little Thompson and Big Thompson creeks, and Cache la Poudre River. These are all large tributaries and have their headwaters in the banks of perpetual snow. At the mouth of Cache la Poudre River the total drainage area of the South Platte River is 9,470 square miles, or nearly four times that above Platte Canyon.

In South Park, at the headwaters of the South Platte River, there is considerable irrigation during the summer season, interfering somewhat with the summer run-off. Irrigation begins, also, where the

river emerges from the mountains and continues all along its course through the State. From the mouth of the Cache la Poudre River the South Platte runs in a northeasterly direction through an arid plains region, in which the rainfall gradually increases going eastward until the humid region is reached. The drainage area at the state line is 20,598 square miles. On the plains little moisture falls in the winter months, but during the summer sharp thundershowers throw large volumes of water into the streams. The country is broad and flat and in many parts sandy, so that the amount of water actually running off is only a small part of that which falls. The reverse is true in the mountains. The hillsides have steep slopes and are rocky, giving little opportunity for the absorption of moisture, and the greater part of the moisture that falls finds its way into the streams.

The soil adjacent to the South Platte River is underlaid with gravel to a large extent. The water used in irrigation finds its way to this gravel and through it to the river channel, becoming a great source of supply to the main stream. As irrigation has increased seepage has increased also, and amounted to 1,042 cubic feet per second in 1907.

From the South Platte River and its tributaries 758 irrigation systems, with a length of 2,725 miles, were supplied in 1902; the cost of construction of these systems was $4,963,319, or an average of $7.20 per acre. The principal crops grown are alfalfa, wheat, oats, barley, potatoes, and sugar beets.[a]

The amount of water carried by the South Platte River is shown by the following table of measurements at four different stations:

Mean monthly discharge of South Platte River at four principal stations.

Month.	Mouth of canyon.	Denver.	Kersey.	Julesburg.
	Cubic ft. per sec.	*Cubic ft. per sec.*	*Cubic ft. per sec.*	*Cubic ft. per sec.*
January	92	113	630	600
February	83	130	636	700
March	155	172	554	739
April	405	451	947	609
May	862	1,110	1,955	1,277
June	743	974	1,480	1,310
July	573	437	207	88
August	409	364	133	179
September	266	225	233	53
October	214	213	458	194
November	190	244	676	406
December	133	126	436	529
Total	274,937	277,327	507,715	406,610

The irrigated area of the South Platte below the mouth of the canyon naturally divides itself into three principal sections, namely, from the canyon to Denver, from Denver to Kersey, and from Kersey

[a] Bur. of the Census [U. S.] Bul. 16, p. 30.

to Julesburg. The following table shows the storage capacity of reservoirs, the return seepage, the areas under ditch, and the areas irrigated in these sections.

Storage capacities of reservoirs, return seepage, and areas irrigated along the South Platte River.

Section.	Storage capacity of reservoir.	Seepage in 1907.	Area under ditch.	Area irrigated.
	Acre-feet.	*Cubic ft. per sec.*	*Acres.*	*Acres.*
Cañyon to Denver	10,438	92	106,809	34,925
Denver to Kersey	18,580	454	91,747	74,549
Kersey to Nebraska line	209,308	498	204,100	109,909

The following table gives similar data for the tributaries of the South Platte, together with the mean monthly discharge in cubic feet per second:

Summary of discharge measurements of tributaries of the South Platte River.

Stream and place of measurement.	Drainage area.	Mean monthly discharge.								
		January.	February.	March.	April.	May.	June.	July.	August.	September.
	Square miles.	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*
Bear Creek at Morrison [a]	170	......	......	......	104	144	151	87	77	40
Clear Creek at Forks Creek [c]	345	......	......	......	124	508	963	513	243	154
South Boulder Creek at Marshall [e]	125	......	......	......	89	284	358	162	66	30
Boulder Creek at mouth of canyon [g]	179	......	......	......	94	361	470	291	143	63
St. Vrain Creek at Lyons [h]	209	......	......	......	175	396	614	360	170	83
Big Thompson Creek at mouth of canyon [h]	305	......	......	......	194	460	734	422	209	99
Cache la Poudre River at mouth of canyon [j]	1,060	96	95	72	193	1,298	2,094	858	341	173

Stream and place of measurement.	Mean monthly discharge—Cont'd.			Average yearly run-off.	Storage capacity reservoir.	Seepage.	Area under ditch.	Area irrigated.
	October.	November.	December.					
	Cu. ft. per sec.	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Acre-feet.*	*Acre-feet.*	*Cu. ft. per sec.*	*Acres.*	*Acres.*
Bear Creek at Morrison [a]	36	22	20	[b] 40,957	10,438	22 (1907)	13,636	11,021
Clear Creek at Forks Creek [c]	122	......	......	[d] 160,393	131,120	14 (1906)	191,425	109,900
South Boulder Creek at Marshall [e]	25	26	......	[f] 63,474	25,451	11 (1907)	86,186	73,306
Boulder Creek at mouth of canyon [g]	38	......	......	[d] 89,266	......	......	......	......
St. Vrain Creek at Lyons [h]	61	27	......	[f] 115,134	25,451	44 (1907)	104,625	104,595
Big Thompson Creek at mouth of canyon [h]	69	51	.....	[f] 136,600	118,147	42 (1907)	[i] 104,799	[i] 97,895
Cache la Poudre River at mouth of canyon [j]	197	86	76	339,926	185,580	139 (1907)	254,680	209,118

[a] 1888–1900.
[b] April to December, inclusive.
[c] 1899–1906.
[d] April to October, inclusive.
[e] Seventeen years.
[f] April to November.
[g] Sixteen years.
[h] Eighteen years.
[i] Includes Little Thompson Creek.
[j] Twenty years.

ARKANSAS RIVER.

The Arkansas River rises in the region of perpetual snow and flows through the mountains a distance of 100 miles to Canyon. In its course through the mountains numerous small streams flow into it. Between Leadville and Canyon, a distance of 100 miles, the fall is 4,700 feet, giving the river the characteristics of a mountain torrent, while east of Canyon it has the characteristics of a plains stream, the channel being broad and sandy and the current constantly shifting from one side to the other. The heavy snows in the mountains melt during the months of May and June, providing a supply of water during the season when most needed for irrigation.

The Arkansas River has many tributary streams in crossing the plains. These tributaries are dry channels during eight months of the year, but are supplemented during the summer months by sudden storms at which times considerable rain falls, causing them to carry large volumes of water for a few hours. This is a great help to the irrigators, giving them a good supply of water after the snow water has passed.

In 1902 the Arkansas River and its tributaries irrigated 388,589 acres, divided into 6,480 farms. The construction cost of the 1,088 systems, including 2,996 miles of main canals, was $4,499,131, or $11.58 per acre irrigated.[a] The 107 systems heading on the main stream irrigate 59.7 per cent of the total irrigated area of the basin, and represent 72.2 per cent of the total construction cost of the irrigation systems.

The principal crops are wheat, oats, barley, cantaloups, and sugar beets. The discharge of the river at various points is given below:

Mean monthly discharge of Arkansas River at three principal stations.

Month.	Canyon.	Pueblo.	Near state line.
	Cubic feet per second.	*Cubic feet per second.*	*Cubic feet per second.*
January	345	379	169
February	383	467	365
March	433	349	600
April	554	508	245
May	1,358	1,582	100
June	2,448	2,344	4,893
July	1,231	1,098	418
August	633	690	178
September	398	354	19
October	401	435	8
November	396	434	16
December	392	384	17
Total annual discharge in acre-feet	545,784	549,690	500,000

The amount of storage capacity of reservoirs taking water from Arkansas River and its tributaries is 403,140 acre-feet. The total amount of seepage on this stream from Canyon to the Kansas-Colorado line, according to measurements made in 1907, is 356 cubic feet per second.

[a] Bur. of the Census [U. S.] Bul. 16, p. 32.

RIO GRANDE.

The Rio Grande heads in the mountains of southern Colorado, flows east through the mountains for 80 miles, thence in a southeasterly direction through the San Luis Valley into New Mexico. This valley is bordered on the west and southwest by the San Juan Mountains and on the east and northeast by the Sangre de Cristo range. It is a broad, fertile plain, having an elevation of 7,500 feet, and contains an area greater than all the agricultural lands in the Rio Grande Valley of New Mexico.

The perennial supply of water comes principally from an area of 2,000 square miles, the greater part of the remaining catchment basin contributing water only in times of heavy rains. The waters of those streams which drain the mountainous areas of the north and northeast sections of the San Luis Valley are lost in the sand and gravel before reaching the Rio Grande. The largest of these streams are the Saguache and San Luis rivers. The artesian basin of the San Luis Valley is a very important one, much of the domestic supply as well as that for irrigation being obtained from this source. The stream is a clear mountain torrent until it enters the San Luis Valley, when it becomes a typical stream of the plains, sinuous, and divided into numerous channels, especially during floods. In this valley it receives the waters of nearly 30 streams, some of the larger of these being Alamosa and La Jara rivers and Rio Conejos. There has been little reservoir construction in this watershed, but storage is needed and will be undertaken, doubtless, in the near future. The principal crops are alfalfa, wheat, oats, barley, potatoes, and Canada field peas. A very large acreage of the latter crop is grown and fed to cattle, hogs, and sheep for fattening. Some experiments made with sugar beets show a good beet with a high percentage of sugar and purity. The following table gives the discharge of the Rio Grande:

Mean monthly discharge of the Rio Grande at two principal stations.

Month.	Del Norte.	Labatos.
	Cubic feet per second.	*Cubic feet per second.*
January	860	543
February	913	716
March	731	430
April	981	418
May	2,586	2,093
June	2,729	2,936
July	922	440
August	490	136
September	420	126
October	529	258
November	394	295
December	613	443
Total in acre-feet	680,220	537,390

The total amount of seepage on the Rio Grande, according to measurements taken in 1907, was 121 cubic feet per second. The total amount of seepage on the Rio Conejos is 10 cubic feet.

The total amount of land under ditches taking water from the Rio Grande and tributaries is 600,000 acres. The total amount irrigated is 406,441 acres.

RATE OF RIVER DISCHARGE.

The larger percentage of moisture falls in the mountain regions during the months from October 1 to May 1, while the larger percentage of run-off occurs during the months from May 1 to September 1, when the snows are melting. The maximum discharge of the streams corresponds very closely with the time of greatest need for irrigation. The period of greatest rainfall on the plains is during the growing season also. This is well illustrated in a comparison of the percentage of monthly discharges of the Cache la Poudre River with the percentages of mean monthly rainfall at the mountain and plains stations, as given in the table below:[a]

Percentage of run-off and of rainfall.

Month.	Run-off, Cache la Poudre.	Rainfall, mountain stations.	Rainfall, plains stations.
	Per cent.	*Per cent.*	*Per cent.*
January	1.75	6.47	2.72
February	1.57	8.25	3.64
March	1.30	10.70	5.79
April	3.40	10.56	12.86
May	23.70	8.48	15.87
June	37.00	5.29	11.71
July	15.54	9.44	15.63
August	6.20	10.61	12.28
September	3.06	9.00	6.64
October	3.58	7.88	6.43
November	1.52	6.48	3.07
December	1.38	6.84	3.36

The greatest need for water for irrigation for all annual crops is from May 1 to September 1, while perennial crops require some water as early as April 1 and as late as October 1. In some portions of the State winter irrigation is practiced with very good results under late ditches on lands intended for plow crops the following year. This is one form of storing water for future use.

The Cache la Poudre River discharges 82.4 per cent of its total run-off during the period of greatest need for irrigation. The rain-

[a] The Cache la Poudre River is taken as typical of mountain streams in Colorado, owing to the size and character of its watershed. There have been some disturbing influences on this river during the latter half of the twenty-year record in the bringing of water from other watersheds, but the data upon this stream are the most complete of any of the important streams of the State.

fall in the mountains during the same period has amounted to 33.8 per cent and on the plains 55.5 per cent of the yearly precipitation. The average period of the winter storage of snow and ice in the mountains is from October 1 to May 1, during which time the stream discharge is 14.5 per cent of the total amount, while the rainfall in the mountains amounts to 57.2 per cent and on the plains 37.9 per cent of the annual precipitation. From these comparisons of the percentage of run-off with the percentage of rainfall it will be seen that the Cache la Poudre River discharges a greater part of the annual rainfall during the four summer months.

No definite information concerning the relative needs of water for irrigation during the different months can be given, as so many elements affect this from year to year and in different locations, but in general these needs are small the first part of May, gradually increasing to a maximum in the latter part of June or the first of July, and decreasing gradually until the last of August or the first of September, when it reaches small proportions again. During the period from May 1 to June 30 the river supply is usually more than sufficient to supply the needs of irrigation, and at that time the reservoirs may be filled. From the last of June until the first of September the river supply is insufficient and must be supplemented with reservoir water. This is true, especially in valleys like the Cache la Poudre, where diversified farming is carried on extensively.

SEEPAGE OR RETURN WATERS.

Water travels through the soil very slowly, the rate being 1 to 1.5 miles per annum. Water carried several miles from the river by a canal and applied to land often requires several years to reach the main stream again. When the water has once traversed the subsoil from the irrigated area to the main stream it becomes a source of increase to the waters of the natural stream and is more or less constant in flow. Seepage measurements taken on the South Platte River since 1889 show an increase in the return waters during that time of more than 600 cubic feet per second. The total amount of return waters to the South Platte River and its tributaries, according to the seepage measurements made by the state engineer's office in the fall of 1907, is 1,317 cubic feet per second, or 961,410 acre-feet per year, which would reclaim 384,560 acres, allowing a duty of 2.5 acre-feet per acre of land. During the irrigation season this water is diverted by canals for use during the next growing season. Much new irrigation development has taken place on the South Platte River during the past five years, due largely to the increase in seepage water, and other irrigated sections are now going through the same development.

The return water to the Arkansas River from the irrigated area has increased very materially during the past few years. In 1897 the total return water from Buena Vista to the Colorado-Kansas line was 250 cubic feet per second. In 1907 the return water from this same section was 356 cubic feet per second, an increase of 106 cubic feet per second in ten years.

DEVELOPMENT OF WATER POWER.

It has been only in recent years that much attention has been given to the development of water power in Colorado, although a few flouring mills have been run by water power for many years, and mining companies and electric-lighting companies have installed a number of small water-power electric-generating plants. In 1900 two comparatively large plants were constructed and several have been built since that date. There are at present 10 water-power plants with a generating capacity of 1,000 horsepower each on different streams of the State, including Beaver Creek, Clear Creek, San Miguel River, Animas River, South Arkansas River, Roaring Fork River, and city water supply of Colorado Springs.

In addition to these, about 42 smaller plants are used to supply power to mines and for electric lighting, having a capacity of from 75 to several hundred horsepower each.

Three large water-power plants are under construction at the present time—one near Glenwood Springs, with a capacity of 10,000 horsepower; one near Boulder, with a capacity of 10,000 horsepower; and one near Lyons, on St. Vrain Creek, with a capacity of 7,020 horsepower.

The amount of horsepower used in manufactures in Colorado in 1900 was 41,412,[a] and in 1905, 119,950. This increase is due largely to the number of sugar-beet factories built during that period. This statement, however, does not include the power used in electric lighting, mining, or transportation.

The following table gives a list of some of the feasible power developments:

Feasible power developments in Colorado.

Stream.	Horsepower.	Stream.	Horsepower.
Cache la Poudre River	30,000	Rio Grande	20,000
North Platte River	20,000	Dolores River	5,000
Big Thompson Creek	20,000	San Miguel River	5,000
St. Vrain Creek	10,000	Uncompahgre River	7,000
Boulder Creek	10,000	Gunnison River	30,000
Clear Creek	12,000	North Fork of Gunnison	25,000
Bear Creek	8,000	Grand River at Gore Canyon	30,000
South Platte River	25,000	Grand River at Glenwood Springs	40,000
Fountain Creek	5,000	Grand River at Hartman Canyon	2,500
Arkansas River	30,000	Roaring Fork River	10,000

[a] Bur. of the Census [U. S.] Bul. 88, pp. 15, 18, and 24.

The power possibilities of the State have scarcely been touched. It is necessary only to secure a market for the power so that capital will be assured of certain returns on the investment, and many of the propositions now lying dormant will be improved. The prices obtained for power vary from $40 to $100 per horsepower per year.

RISE AND PROGRESS OF IRRIGATION.

PRIVATE ENTERPRISES.

The early gold seekers found agriculture by irrigation profitable. The first large colony of white men in Colorado, fostered by Horace Greeley, settled on the Cache la Poudre River, about 52 miles north of Denver, in 1870. These settlers began the construction of canals at once. The first ditches taken out watered the bottom lands, but it was soon found that the uplands were easier to subdue and gave as great returns as the bottom lands. The early ditches were taken out at the easiest places and little was known of the methods of applying water to crops or the amount of water required, more water being applied whenever the ground looked dry. The first canals were constructed by a single man, or by two or more working together, each sharing equally in the water obtained and in the expenses necessary to keep up the repairs. No flumes were used and cheap wooden headgates were put in. Later, men with capital came and built larger and longer canals and organized ditch companies to better enable them to handle the business connected with the canal. However, nearly all the structures on all the early canals were of wood, which soon decayed and gave way, often causing serious breaks in the canal and consequent losses of water when it was greatly needed for crops. The building of the larger canals soon exhausted the flow of the streams at the lower stages and the question of rights to water became important. The constitution of the State gave the older canals the better rights, but the machinery for carrying this doctrine into effect was lacking for years.

In 1879 the legislature created the office of water commissioner and passed an act whereby a ditch could get a decree of the district court for the amount of water to which it was entitled and establish the date of its appropriation. In 1881 the office of state engineer was created, and in 1887 that of superintendent of irrigation, which was changed afterwards to irrigation division engineer.

In districts where there were conflicts application was made to the district court for decrees, but the courts in granting such decrees were at a loss to know what amount of water was necessary to irrigate the land properly. They were liberal, nearly all the decrees being granted on the basis of 1 cubic foot per second for each 50

acres of land. And some courts adopted even a lower duty, 1 cubic foot per second for each 25 acres. The result of this lack of knowledge was that the older canals secured rights to more water than was needed for the lands under them. The ditches were eventually extended, however, and more land was brought under cultivation.

Not realizing that the difference in climatic conditions made so great a difference in the crops, farmers brought with them seed of the plants they were accustomed to growing in the East. Corn, wheat, barley, and oats were planted for many seasons. The small grains did fairly well, but corn gave indifferent returns. Later, alfalfa was planted. It did remarkably well, and proved to be wonderfully hardy, vigorous, and a rapid grower, giving as high as three crops per year. It not only gave good returns but also enriched the soil by collecting nitrogen from the air and storing it in the soil. Potato growing also met with success in certain favored localities.

For a number of years agriculture was confined to alfalfa and the growing of small grains, supplemented with live-stock raising. These crops did not require many irrigations, as the spring rains generally sprouted them and the melting snows in May and June gave sufficient water for one or two irrigations, which were enough to mature the crops. It was found later that growing cantaloups, potatoes, and sugar beets was more profitable than small grains. The streams, however, did not furnish the supply of water when these crops needed it, and to insure late water supply it was necessary to store the winter and surplus flood waters in reservoirs, for which, fortunately, many natural sites were available at small expense. A farmer whose crops are two-thirds grown, cultivated, and needing only one irrigation to bring them to maturity can afford to pay a high price for that one irrigation. Farmers commencing their spring seeding with reservoirs filled with water can have complete confidence that their labors will be repaid with abundant harvests, reservoir water being an insurance against failure or shortage of crops due to a scarcity of water. No one feature of irrigation stands out so prominently in Colorado as water storage.

Reservoir development began on the Cache la Poudre River about 1890 and has progressed steadily, until now it has reached its highest development in this locality. The total storage capacity of the reservoirs amounts to 55 per cent of the average yearly run-off of the Cache la Poudre River at the canyon. Stored water in this section is commonly sold by the million cubic feet (23 acre-feet) and brings \$50 to \$125 per million cubic feet, this high value being due to the fact that the majority of reservoirs are used to supplement canals that had already obtained a partial supply from the river.

With the development of reservoirs has come also the construction of mountain ditches to divert water from other watersheds, where water is abundant and not much land available for irrigation. The most notable of these mountain ditches are the Skyline Canal of the Water Supply and Storage Company, diverting water from the Laramie River over a low divide into the Poudre River; the Grand River Ditch, owned by the same company and diverting water from the headwaters of Grand River over a low pass in the Continental Divide into the Big South River; the Michigan Ditch, owned by the North Poudre Irrigation Company, and diverting waters from Michigan River, a tributary of the North Platte River, over Cameron Pass into Joe Wright Creek; and the Sand Creek Ditch, owned by Bruce Eaton, and diverting water from the tributaries of the Laramie River into Sheep Creek, a tributary of the North Poudre River. The water thus diverted from other watersheds is used in the same manner as reservoir water.

Irrigation of grain and alfalfa was first practiced by flooding. Under that system an irrigator would look after two or three streams of water flowing upon the ground and spreading out in as many places. Careless irrigators would often leave the water running in one place for twenty-four hours. As the land and the water became more valuable better methods were introduced, and now, where it is possible, crops are irrigated by allowing water to run down furrows. An irrigator gives his time continuously to the proper distribution of a single head of water. This method is more economical in the use of water, and when practiced the surface of the soil does not bake or harden in the sun so badly as where flooding is practiced. As soon as possible after an irrigation by the furrow method the ground is cultivated in order to form a mulch and prevent the evaporation of the moisture from the soil. Owing to this change of methods water rights which were originally serving only 50 acres are now doing duty for 80 to 100 acres. When the decrees were first granted ignorance of the law on many points caused many to think injustice had been done in certain cases, and the water commissioners at first often experienced some difficulty in distributing the water of a river, as farmers whose crops needed water would open their headgates and take the water. The irrigators have now learned to respect the decrees of the court and this practice has gradually been dropped. The water commissioners, as a rule, have been fair and energetic in the discharge of their duties and the irrigators have come to have confidence in them.

It is now the practice in the Arkansas Valley for the irrigation division engineer and the water commissioners to issue a report

every evening, giving the amount of water carried by each ditch, the amount received from the tributaries, and the amount in the river at the head of each water district. This information is reported by telephone to a central station and there copied onto blank forms and mailed to the canal superintendents and irrigators, who receive them the next morning. This information covers a length of river of 300 miles and is of great value to the irrigators and of much assistance to the water officials in the discharge of their duties.

The first ditches taken out were built by one person, or sometimes by two or three persons working together. The larger canals, however, have been built by stock companies, organized usually under the laws of the State by owners of the lands under the proposed canals, and each stockholder is entitled to such a proportional share of the water carried by the ditch as his stock is of the capital stock of the company. Annual meetings of the stockholders are held at which a board of directors is elected, assessments are voted to pay the cost of running the ditch, and resolutions, authorizing the board of directors to make needed improvements, are passed. The board of directors elects its own officers, employs a superintendent and ditch riders to operate the canal, and transacts all business of minor importance. Such questions as the construction of new reservoirs, building extensions, or borrowing money for needed improvements, are usually referred to the stockholders' meetings for decision.

The superintendent of the canal directs the turning of the water in and out of the canal, keeps a close watch on the river that he may know when his ditch is entitled to water, gives the ditch riders their instructions, supervises the division of water between the various water users, and has general charge of the ditch. Each ditch rider usually looks after 10 or 15 miles of ditch, sometimes more. He furnishes his own horse and buggy, but is furnished a house to live in and the tools needed in his work. With some of the largest canals, it is necessary to have riders to look after the distribution of water from the laterals. The laterals under the larger systems are generally under the control of a lateral company, and after the water leaves the main canal the ditch companies cease to be responsible for it. In case of the smaller ditches, the farmers themselves attend to turning water in or out.

Under the laws of Colorado canals are common carriers and farmers owning water in a reservoir not controlled by the ditch company are able to get this water brought to their lands by paying a carrying charge, usually about $2 per million cubic feet.

The expenses of superintendent, ditch riders, repairs, and improvements are borne by the company. An estimate of the expenses for

the coming season is made and assessments levied at so much per share. These assessments run from 25 cents to $1 per acre, although for ditches located very favorably they may be smaller.

CAREY ACT PROJECTS.

By an act of Congress, approved August 18, 1894, the Secretary of the Interior, with the approval of the President, is empowered to contract and agree to patent to States having desert lands, not to exceed 1,000,000 acres of such lands under certain conditions. The tenth general assembly of Colorado, by an act approved March 15, 1895, accepted the conditions and the grants of land to the State under this act, and provided for the manner in which the irrigation and disposal of the lands should be carried out. The selection, management, and disposal of these lands are vested in the state board of land commissioners. The manner of procedure in selecting, reclaiming, and disposing of this land and specifying the several steps to be taken from the first request for the selection of the land to the final disposition of it to settlers are provided for in detail.

The Carey Act was amended June 11, 1896, making provision that a "lien is authorized to be created by the State to which such lands are granted, and where created shall be valid on and against the separate legal subdivision of land reclaimed, for the actual cost and necessary expenses of reclamation and reasonable interest thereon from the date of reclamation until disposed of to actual settlers, and when an ample supply of water is actually furnished in a substantial ditch or canal, or by artesian wells or reservoirs, to reclaim a particular tract or tracts of such lands, their patents shall issue for the same to such State without regard to settlement or cultivation." This act allows the construction company, which contracts to build the canal, ditch, or reservoir for the reclamation of the land, to mortgage its equity in the project to obtain the money required to properly complete the necessary works.

Since the approval of this act, March 15, 1895, six applications have been received to reclaim lands under the conditions prescribed by the Carey Act. Of these projects one was withdrawn, two canceled, and three are being carried out. Below is a brief description of these three projects.

The Colorado Realty and Securities Company made application on January 10, 1903, to reclaim 37,825.47 acres in Routt County, lying in township 12 north, range 93 west; township 12 north, range 94 west; township 11 north, range 94 west; township 9 north, range 95 west; township 10 north, range 95 west; township 11 north, range 95 west; township 9 north, range 96 west; township 10 north, range

96 west, of the sixth principal meridian. It was proposed to water these lands from Snake River by a canal 49 miles long, having a capacity of 632 cubic feet per second. The estimated cost of canal, headgates, and dam is $201,500. The lands were examined and plans of the proposed works approved by the state engineer on January 8, 1903.

John T. Noonan made application for 2,200 acres in township 4 south, range 5 west. These lands are to be irrigated by storing the flood waters of Muddy Creek in reservoirs. The estimated cost of reservoirs is $30,000. This application was approved by the state engineer July 28, 1904.

The Colorado Land and Water Supply Company made application on April 8, 1906, for 16,277.5 acres lying in township 33 north, range 7 west; township 33 north, range 8 west; township 34 north, range 8 west; township 33 north, range 9 west, of the New Mexico principal meridian. An examination was made into the available supply of water, and the application was approved by the state engineer.

RECLAMATION SERVICE PROJECTS.

Only one United States reclamation project is under construction in Colorado—the Uncompahgre Valley project. A tunnel 30,583 feet long has been constructed through a mountain range to divert the waters of Gunnison River to the Uncompahgre Valley, near Montrose, Colo. The tunnel is 10.5 by 11.5 feet in cross section, with a fall of 2 feet in 1,000 feet, and will have a carrying capacity of 1,300 cubic feet. On January 1, 1910, the tunnel was 87.6 per cent completed, the remaining work being enlarging, timbering, and lining of certain sections.

In connection with this project, 77 miles of canals have been built and existing canals, have been purchased. In case of the existing canals, it is the intention to supplement the supply of water from Uncompahgre River by water from the Gunnison River. The acreage under existing canals is estimated at 30,000 acres. The total irrigable land in the project is 146,000 acres. The entire project is 55.5 per cent completed.

The first estimate of the cost of water rights was $25 per acre, but unforeseen difficulties have increased the cost, and at the present time it is estimated that water will cost $35 per acre. This is to be paid in ten equal annual payments without interest, the first payment to be made one year after water is turned into the irrigation canals. The crops that can be grown are alfalfa (three crops), cereals, sugar beets, fruits, and vegetables. The value of the land with water will vary from $50 to $500 per acre. Most of the land

in this project was government land at the time the scheme was started, and 20 per cent of it now belongs to the United States Government, the remainder having been taken up under the United States land laws and the water subscribed for. Tracts of this land are for sale at reasonable prices.

IRRIGATION DISTRICTS.

The present law in relation to irrigation districts (law of 1905, chap. 113) was passed by the fifteenth general assembly in lieu of the one passed by the thirteenth general assembly, and is designed to enable the users of water to own and control their own irrigation works and to administer the business affairs. The districts are made quasi-municipal corporations, with power to construct reservoirs, canals, and laterals; to issue bonds for the payment of the same, and to provide a method for taxing the lands in the district to meet the operating expenses, interest, and principal of the bonds. The bonds so issued are valuable as investment securities, and there is no serious difficulty in selling them at par if the formation of the district and the voting of the bonds are properly performed and safeguarded. Under the provisions of this act the settlers are enabled to combine for the immediate construction of needed irrigation works for the full development of their farms. The duty of water is much higher, also, under the intelligent management of district officers, and the cost of maintenance, when carefully safeguarded, is reduced to a minimum.

The assessments for the payment of construction should not be burdensome, as the bonds are paid in a series of years, and the united action of the settlers enables each to bring his farm into cultivation at an earlier date and at a much less cost than would be possible if acting individually.

Although the quasi-municipal power vested in an organized irrigation district may be considered the most essential feature, still a salient point no less advantageous to the district is the local community interest in the management of its affairs, by means of which each district can adopt the best methods for maintaining such works and distributing the water to the greatest advantage to each settler.

Another matter of importance is the comparatively small expense incident to the management of the district affairs, as each community has men eminently qualified to carry on the business of the district. All questions pertaining to district matters can be adjusted without recourse to the courts, and without loss of time and delay attaching to court proceedings. On page 30 is shown a list of irrigation districts formed in Colorado, together with information concerning them.

Table of irrigation districts, dates of organization, secretaries, bonds voted and sold, lands to be irrigated, and lands previously irrigated.

District.	Date of organization.	Secretary.	Amount of bonds voted.	Amount of bonds sold.
Bent & Prowers	July 23, 1906	A. E. Downer, Lamar	$1,300,000	None.
Bijou	July, 1905	Galway Layton, Fort Morgan	750,000	$700,000
Fort Morgan	1904	L. C. Baker, Fort Morgan	178,000	178,000
Grand Valley Irrigation District No. 1.	Oct. 26, 1903	H. E. Wagner, Fruita	585,000	None.
Grand Valley Irrigation District No. 2.	Jan. 20, 1904	H. J. Pomroy, Palisade	180,000	None.
Green City	June 19, 1906	E. E. Moore, Masters	46,000	40,000
Henry Lynn	Oct. 8, 1907	J. H. Ledgerwood, Hudson	3,000,000	None.
Hillrose	Feb. 20, 1905	D. D. Monroe, Hillrose	70,000	70,000
Julesburg	July, 1904	E. J. Fredricks, Julesburg	465,000	465,000
Mesa County	Jan. 12, 1906	R. H. Bancroft, Palisade	100,000	100,000
Montezuma Valley	Dec. 7, 1901	W. F. Mowry, Cortez	795,000	795,000
Nile	July 20, 1908	John Myers, Wiggins[a]	700,000	None.
North Sterling	Feb. 25, 1907	W. B. Giaconnie, Sterling	2,080,000	50,000
Orchard Mesa	Mar. 18, 1904	E. E. Udlock, Grand Junction	900,000	840,000
Otero	1902	Geo. A. Kilgore, La Junta	500,000	460,000
Palisade	Oct. 31, 1904	R. H. Bancroft, Palisade	160,000	160,000
Park Creek	Sept. 24, 1908	R. Q. Tenny, Fort Collins	72,000	None.
Riverside	Mar. 11, 1907	L. W. Beem, Orchard	740,000	720,000
San Arroya	June 30, 1908	W. A. Dregman, Fort Morgan	235,000	None.
Total			12,856,000	4,578,000

District.	Date of organization.	Secretary.	Number of acres of land it is proposed to irrigate.	Number of acres of land previously irrigated.	Number of acres of land to be reclaimed.
Bent & Prowers	July 23, 1906	A. E. Downer, Lamar	75,000	None.	75,000
Bijou	July, 1905	Galway Layton, Fort Morgan	40,000	3,000	37,000
Fort Morgan	1904	L. C. Baker, Fort Morgan	12,500	12,500	None.
Grand Valley Irrigation District No. 1.	Oct. 26, 1903	H. E. Wagner, Fruita	30,000	1,000	29,000
Grand Valley Irrigation District No. 2.	Jan. 20, 1904	H. J. Pomroy, Palisade	5,160	None.	5,160
Green City	June 19, 1906	E. E. Moore, Masters	2,000	None.	2,000
Henry Lynn	Oct. 8, 1907	J. H. Ledgerwood, Hudson	100,000	None.	100,000
Hillrose	Feb. 20, 1905	D. D. Monroe, Hillrose	12,000	12,000	None.
Julesburg	July, 1904	E. J. Fredricks, Julesburg	22,500	7,500	15,000
Mesa County	Jan. 12, 1906	R. H. Bancroft, Palisade	2,600	100	2,500
Montezuma Valley	Dec. 7, 1901	W. F. Mowry, Cortez	50,000	15,000	35,000
Nile	July 20, 1908	John Myers, Wiggins[a]	13,000	None.	13,000
North Sterling	Feb. 25, 1907	W. B. Giaconnie, Sterling	80,000	None.	80,000
Orchard Mesa	Mar. 18, 1904	E. E. Udlock, Grand Junction.	12,000	800	11,200
Otero	1902	Geo. A. Kilgore, La Junta	20,000	4,000	16,000
Palisade	Oct. 31, 1904	R. H. Bancroft, Palisade	5,600	2,800	2,800
Park Creek	Sept. 24, 1908	R. Q. Tenny, Fort Collins	5,000	None.	5,000
Riverside	Mar. 11, 1907	L. W. Beem, Orchard	40,000	None.	40,000
San Arroya	June 30, 1908	W. A. Dregman, Fort Morgan.	14,000	700	13,300
Total			541,360	59,400	481,960

[a] Also called Corona.

IRRIGATION BY PUMPING.

Pumping for irrigation has received some attention and in many places has proved successful, while in others it has failed. Gasoline engines have been the motive power in many of the smaller plants, owing to the low first cost and the small amount of attention required in operating. Some steam plants and a few electrical ones are used.

In the eastern part of the State all the pumping is done from wells sunk into the water-bearing sands and gravels and consequently only small tracts—40 to 100 acres—can be served. Large acreages can be irrigated from a single plant only where the pumping is done from large running streams.

In the early days of irrigation it was cheaper to build canals and allow the water to run onto the land than to lift it to the same elevation by mechanical means, but to-day in the older-settled districts, where all projects having a cheap first cost have been constructed and where the value of water rights under them have greatly advanced, the people are turning their attention to pumping plants.

The cost of installing a small pumping plant—well, pump, and engine—is generally less than the cost of a first-class water right, and where the water supply is ample there is no good reason why a pumping plant can not be made a success. Failures have been due either to mechanical defects in the pump or engine or, more frequently, to an insufficient supply of water in the well. The first essential for a pumping plant is a water-bearing gravel capable of furnishing an ample water supply within a reasonable distance of the surface.

Irrigation by pumping is barely past the experimental stage. Enough has been done, however, to show that it can be made a success. As the value of products raised on an acre of irrigated land increases the value of land and water will increase and will justify a greater expense in securing water. Pumped water will in some places take the place of reservoir water, supplying the crops with water at times when the stream flow is not sufficient. A good example of the value of pumping is given in the following description of the Darnell & Fuller pumping plant, taken from the annual report of Irrigation and Drainage Investigations, 1904:[a]

This well is on a table-land four blocks south of Main street in Windsor.[b] It is 8 by 16 feet and 25 feet deep. Water occurs in sand and gravel at about 15 feet from the surface. It is curbed with 3-inch timber, the frames being made of 4 by 6 inch timbers. When being pumped at the rate of 441 gallons per minute, water stood 6 feet from the bottom of the well. The curb was built on a frame as the excavation was carried on, and was lowered by being weighted by boxes of sand and gravel. The well cost $425.

Water was raised by a No. 4 vertical centrifugal pump and discharged through a 5-inch galvanized-iron pipe 27 feet long. The lift varied from 21 to 27 feet. With the engine running at a speed of 185 revolutions per minute the pump discharged 441 gallons. The cost of pump and connections was $125.

The pump was driven by an 18-horsepower horizontal-cylinder gasoline engine set in concrete. The fuel consumption was 1.1 gallons of gasoline per hour, gasoline costing 20 cents per gallon. Oil cost about $5 for the season. The engine cost $950.

Fifty acres in potatoes, beets, and fruit were supplied with water, although this land received some ditch water. This plant was established in February, 1904, and

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[a] U. S. Dept. Agr., Office Expt. Stas. Bul. 158, pt. 8, p. 599.

[b] Now New Windsor.

was run every day during the irrigation season from 5 a. m. to 10 p. m. The owner is fully convinced that the establishment of this plant is a profitable investment, although the returns for the season were not complete at the time the plant was visited. Reservoir water can be secured for this land for $80 per year. This guarantees a run of 30 inches for ten days. The cost of pumping this quantity for the same length of time is about one-half as much.

The entire cost of the well and plant was $1,500, or $30 per acre for the 50 acres irrigated.

This plant is typical of many of the pumping plants located east of the mountains and shows to what use pumps may be put and how, like reservoirs, their greatest value is in furnishing a supplemental supply in times of scarcity.

On the western slope in the vicinity of Grand Junction several pumping plants are pumping direct from the Grand River and operated by steam, water power, and electricity. At Grand Junction, which is in the center of the western slope fruit belt, land with water has a value of several hundred dollars per acre, justifying a considerable outlay for water.

One of the largest plants operated by water power is the Redlands irrigation system, located on the south side of the river opposite Grand Junction. This system consists of a power canal with a capacity of 550 cubic feet per second, 450 cubic feet per second of this amount being used to drive the water wheels now operating under a head of 36 feet, but which will be increased to 42 feet eventually by excavating the tailrace to grade. With the latter head the wheels will develop 1,720 horsepower, 1,180 of which is required to operate the pumps, leaving an excess of 540 horsepower. It is proposed to lift 52 cubic feet per second a distance of 130 feet the water to be used for the irrigation of 4,000 acres of choice fruit lands.

Water rights have been sold by the Redlands company at $100 per acre, which will be the price also under the second lift. The annual maintenance charge is fixed by contract at $2.50 per acre, and that for the lands under the second lift will be $5 per acre. There are about 1,200 acres which can be watered by a second lift for which the excess power generated at the power house can be used.

Cost of pumping of plants near Grand Junction, Colo.[a]

Owner.	Lift.	Cost per acre.	Power used.
	Feet.		
G. R. Warner	12	$6.70	Electricity.
George Smith	90	12.57	Steam.
Wallace Orchard Co	35	3.97	Do.
Hand and Smith	82	12.53	Hydraulic.
Elgin Water and Power Co	55	7.92	Steam.
Mutual Mesa Irrigation Co	85	8.86	Hydraulic.
Rod McDonald	85	11.38	Steam.
Mesa County irrigation district	....	9.06	Hydraulic.
Palisade Irrigation District No. 1	34	4.81	Do.

[a] Thesis on "Cost of Irrigation by Pumping," Harry Soverign, Univ. Colo., 1908.

These plants take water from large runn ater off
to irrigate fruit land upon which the crop r
item of cost per acre per season is made up of int
cost of installing the plant, an allowance for dep
actual cost of operation. It is readily seen that wit
of operation, due in a measure to the lift, pumping for i
pay only where the crop gives a large return per acre.

HISTORY OF THE SUGAR-BEET INDUSTRY.

The construction of a beet-sugar factory at Grand Island, Nebr., in 1885 caused the Colorado farmers to study conditions for the growing of sugar beets. Several experimental lots were grown in various parts of the State from samples of seed furnished by the United States Department of Agriculture. The matured beets were sent to Washington for analysis and almost invariably showed high percentages of saccharine matter and purity. The agricultural experiment station at Fort Collins made a number of experiments with sugar beets and published the results.

The first sugar-beet factory in Colorado was erected at Grand Junction in 1899 by the Western Sugar and Land Company, the capacity being 350 tons of sugar beets per day. It is reported that the first season this factory manufactured 1,500,000 pounds of refined granulated sugar. It had a rather hard struggle in its early history, as sugar-beet growing was not successful at first, and after one or two trials was abandoned by the farmers. The factory remained idle for one or two seasons until the success of factories in other parts of the State aroused renewed interest in sugar-beet cultivation. The farmers were induced to grow sugar beets again, and the second effort met with such success that the Grand Junction factory has proved to be one of the most prosperous in the State.

The attention of the American Beet Sugar Company had been called to the advantages of Colorado for the growing of sugar beets, and in 1900 it erected a sugar factory at Rockyford, with a capacity of 1,000 tons of beets per day. An area of 8,000 acres was subscribed for the first season, about 4,000 acres planted, and about 40,000 tons of sugar beets harvested. That season proved successful to both the grower and the factory.

A factory with a capacity of 500 tons per day was established the same year at Sugar City by the National Sugar Manufacturing Company. The success of the early factories stimulated the establishment of others, and in 1901 a factory with a capacity of 500 tons per day was constructed at Loveland. This factory was afterwards enlarged to a capacity of 1,200 tons. Since that date other factories have been built in the State. The following is a list of the sugar-

factories in Colorado with the dates of their erection and daily capacities:

Location, dates of erection, and daily capacities of sugar-beet factories in Colorado.

Location.	Date of erection.	Daily capacity.	Location.	Date of erection.	Daily capacity.
		Tons.			*Tons.*
Fort Morgan	1906	600	Grand Junction	1899	600
Brush	1906	600	Rockyford	1900	1,100
Greeley	1902	600	Lamar	1905	600
Eaton	1902	600	Las Animas	1907	700
Sterling	1905	600	Sugar City	1901	500
Windsor	1903	600	Holly	1905	600
Fort Collins	1903	1,200	Swink	1906	1,200
Longmont	1903	1,200			
Loveland	1901	[a] 1,200	Total		12,500

[a] Enlarged from 500 tons capacity.

In 1908 119,475 acres of sugar beets were grown, and 1,108,961 tons of beets ground. A total of 244,560,000 pounds of sugar were produced, which at 4 cents per pound would amount to $9,782,400. The industry has grown to these proportions in eight years. The climate of Colorado is particularly suited to this crop. The sunshine allows the beet to ripen and acquire a high saccharine content, while the dry weather favors the harvesting of the crop. Agricultural experts employed by the beet-sugar companies visit the farmers and offer assistance in the way of teaching proper methods of plowing, cultivating, fertilizing, and crop rotation.

NEW IRRIGATION PROJECTS.

On the following projects, except that of the Uncompahgre Valley, the work was completed in time to have water flowing through the canals for the crop season of 1910:

New lands which will be brought under irrigation in 1910.

Project.	Acres.	Project.	Acres.
Uncompahgre Valley project, by United States Reclamation Service	137,000	Denver Reservoir Irrigation Co	20,000
North Sterling irrigation district	80,000	Orchard Mesa irrigation district (fruit land)	11,200
Two Buttes (Carey Act)	22,000		
Henrylyn irrigation district	100,000	Total	370,200

IRRIGATION LAW AND PRACTICES.

ACQUIREMENT OF RIGHTS.

The right to divert the public waters was early recognized. This doctrine is directly opposed to the riparian-rights doctrine, which has been handed down to many States from the common law of England. Necessity has been the mother of each doctrine, as the one makes the best possible use of the water in an arid country, while the other is

adapted to a country in which the chief problem is to get the water off the land and into the sea. The constitution of the State of Colorado declares that "the water of every natural stream not heretofore appropriated, within the State of Colorado, is hereby declared to be the property of the public, and the same is dedicated to the use of the people of the State, subject to appropriation as hereinafter provided," * * * and that "the right to divert unappropriated waters shall never be denied. Priority of appropriation shall give the better right as between those using the water for the same purpose." Thus under the laws of Colorado the first man who constructed a ditch and diverted the water from a public stream and put it to a beneficial use has the first right, the second man has the second right, and so on to the last man. At times of low water, if there is not enough to supply all, the water is distributed as far as it will go, and the later appropriators are obliged to do without until such time as the stream rises again. The State realized the necessity and importance of irrigation, and as an inducement to the farmer to put land under cultivation gave him the use of what water he could apply beneficially. The State does not dispose of the water itself, however, but only the use of the water. It makes a distinction between parting with its title to water and granting the use of the water. To all intents and purposes the appropriator has full control of the water, except that he can not waste it, and his title to or control of it ceases when the water has completed the use for which it was appropriated. For example, if a farmer has a right to a certain quantity of water for the irrigation of 1,000 acres of land, when that amount of water has been used during the season the irrigation of the land is completed and the water in the stream goes to the next appropriator.

The steps to be taken in acquiring the right to use water are similar to those in proving up on government land. It is necessary that a survey of the proposed ditch or reservoir first be made and duplicate maps filed with the state engineer. If correct, these maps are approved, the duplicate being filed with the county clerk of the county in which the headgate of the ditch or reservoir is to be located. The ditch or reservoir is then constructed and the water applied to the soil, after which a decree is secured from the district court giving the amount of water to which the ditch or reservoir is entitled and the date of the appropriation. This decree of the district court is the guide for the water commissioner in distributing the waters of his district. A decree can not be reopened or attacked after four years, except on the ground of abandonment. The only way a water right can be lost is by abandonment, and there is no statutory limitation for abandonment in Colorado; each case must be decided upon its merits.

The use of water is a property right and can be sold. The character of use of water may be changed from an agricultural use to domestic or manufacturing use. The place of use may be changed also, on application to the district court.

ADMINISTRATION OF THE LAWS.

At the head of the Colorado irrigation system is the state engineer, some of whose duties are to gage the streams and administer the laws relative to irrigation. Under the state engineer are five division engineers, each having charge of an irrigation division, which usually comprises a large drainage area, such as the South Platte River or the Arkansas River and their tributaries.

The State is divided into 70 water districts, each of which generally comprises one of the tributaries to the main drainage stream or such portion of the main stream as one man is able to look after, and is about as large as a county, but conforms to drainage lines rather than county lines. Each district is in charge of a water commissioner, who distributes the water in his district according to the decrees granted by the district court, and who is clothed with police power and has authority to arrest anyone violating his orders relative to the opening or shutting down of headgates over which he has direct supervision. Some water commissioners, having districts in which the ditches are scattered over large areas or in which the services of several men are required to look after all of the canals, have several deputies. Each water commissioner makes up a crop and irrigation report for his district in the fall, after the irrigation season is over, giving the number of acres planted in the different crops and the amount of water carried by the several canals.

Each division engineer has general supervision over the water commissioners in his division and directs the closing of canals in upper water districts to supply senior decrees in lower water districts. Complaints against the actions of water commissioners are made to him and an appeal can be taken to the state engineer from his decision. He compiles the irrigation crop reports made by the several water commissioners in his division. Each year, between November 15 and 30, the five division engineers meet with the state engineer in Denver, submit their annual reports, and discuss the many questions which arise in the discharge of their duties.

EXCHANGING RESERVOIR WATER.

No one factor has been so important in the development of reservoirs in the Cache la Poudre Valley as the system of exchanging reservoir water with the river. This system has been evolved during the past fifteen years and has reached large proportions. As a description of this method of exchange will be of interest to those connected with irrigation in other sections, a part of the report of

J. L. Armstrong, water commissioner of district No. 3, presented to the state engineer in 1904, covering the system of exchange in practice on the Cache la Poudre River, is given:

The North Poudre Canal is the latest large irrigating ditch in this district and depends mainly on its reservoirs for its water supply. Three of the largest of these, with a combined capacity of 1,040,000,000 cubic feet, are lower than the lands to be irrigated, and the water stored in them can be used only by exchange with the river or ditches below them. The largest of these, known as Fossil Creek Reservoir, is situated about 40 miles down the river and on the opposite side from the head of the North Poudre Canal. The water of this reservoir is discharged into the river in exchange for the water diverted from the river 40 miles above the North Poudre Canal, and in exchange for water taken by a number of other ditches above and below Fort Collins, some of whose stockholders have purchased shares of the North Poudre Irrigation Company to insure them late water for beets and potatoes.

A stockholder in one of these other ditches, who owns one share of stock of the North Poudre Irrigation Company, was entitled to have 129,600 cubic feet of water turned into the ditch which covers his farm when that ditch can not get any water on its own appropriation. * * *

The water of the other two reservoirs, known as Nos. 5 and 6, is disposed of by a somewhat different method. They are on the north side of the river below the North Poudre Canal and above the Larimer County Ditch, owned by the Water Supply and Storage Company, which owns also reservoirs below its canal and discharges them into the third largest canal on the north side—the Larimer and Weld Canal. Now, some of the stockholders of the Larimer and Weld have about 300,000,000 cubic feet of water stored in the Windsor Reservoir, which is below the canal they irrigate from, and is discharged into Greeley No. 2 Canal, the fourth and last large ditch on that side of the river. Greeley No. 2 Canal has the best water right, and a part of its appropriation is turned into the North Poudre Canal, which is paid for by turning an equal amount from reservoir No. 6 into the Larimer County Ditch. The owners of this ditch pay for the water thus received by turning the same quantity from its reservoirs into the Larimer and Weld Canal, for the use of stockholders of the Windsor Reservoir, who in turn pay their debt by discharging the water from Windsor Reservoir into Greeley No. 2, which pays No. 2 for that part of its appropriation which was taken by the North Poudre Canal.

It is not always desirable to make all the exchanges at the same time; for instance, while the Windsor would deliver 100,000,000 feet to No. 2, during the first ten days of July to pay for what the North Poudre Canal had taken, it might prefer to leave that amount on deposit in the Water Supply and Storage Company's reservoir, to be drawn in August, or even in September.

This makes it necessary to keep an account with each company, and, while the law does not say so, the water commissioner is expected to be the bookkeeper, and he certainly needs to be very handy with a pencil.

But the extra work is nothing compared with results and that is what the Poudre Valley farmers seem to be after. One of these results is that four sugar factories in the Cache la Poudre Valley have done a good big business during the last two years, while without the reservoir system one would have been too many.

The North Poudre Canal carried 396,910,400 cubic feet of exchange water from June 19 to September 14. The North Poudre Irrigation Company also delivered to the following canals the amounts below for stockholders in its company, but drawing their water through other canals.

Water delivered by North Poudre Canal by drawing water through other canals.

Name of canal.	Cubic feet.	Name of canal.	Cubic feet.
Larimer and Weld Canal	105,412,300	Lake Canal	16,400,000
Poudre Valley Canal	84,860,800	Fort Collins Canal	5,000,000
Greeley No. 2	69,120,000	Emeigh Ditch	1,100,000
Larimer County No. 2 Canal	63,348,000	Vandewark Ditch	800,000
New Mercer Canal	50,502,700		
Pleasant Valley Canal	33,200,000	Total	429,743,800

All of the former and a portion of the latter amounts were exchanges with the river. The total amount of reservoir water delivered by this company for the season was nearly 827,640,000 cubic feet, or 19,000 acre-feet, the most of which could be used only for a system of exchanges. Another feature in regard to these exchanges is the importance of having the stored water as high up in the stream as possible in order to give greater opportunity for exchanging not only with the river but with other reservoirs. The opportunities for storing water from the return waters of both irrigation and floods are greater, however, on the lower stretches of the stream. To overcome this the North Poudre Company has developed to some extent a double system of reservoirs and exchange. As mentioned in the report of Mr. Armstrong, their Fossil Creek Reservoir is situated about 40 miles down the river from the intake of the irrigation canal. This reservoir is filled in the winter and early spring months, and as soon as irrigation begins Fossil Creek water is exchanged for river water, the river water being taken out by the North Poudre Canal and stored in reservoirs higher up the stream.

The water diverted from the Laramie and Grand rivers by the Water Supply and Storage Company and the diversions of several other companies from other watersheds has been used also in the exchanges with the river.

In the development of hydro-electric plants on many of the streams the conflict with irrigation and storage rights has been a serious one. The water of many of the streams in normal years is fully appropriated for irrigation and storage. Irrigation requires its stored water in the late summer, while power demands it during the fall and winter, and the use of the same water is therefore impossible. This difficulty can be overcome, however, by a system of double storage and exchange. The Central Colorado Power Company proposes to use such a system in the development of its Boulder Creek plant. Here the water will be stored in mountain reservoirs for use in winter, re-stored in a valley reservoir after having passed through the plant, and exchanged in the summer season for water stored in the mountain reservoirs. Thus the only drain upon the stream after the first filling of the reservoir will be the losses by seepage and evaporation.

DRY FARMING.

Stretching from the mountains to the eastern border of the State, lies a country upon which the rainfall varies from 11 to 15 inches per annum. The rainfall being not only scant but also uncertain as to time makes agriculture still more precarious. Portions of this country were settled about 1887 by what are now called "dry farmers," who attempted to farm this semiarid region without the aid of irrigation. These early settlers met with success at first, but the few wet years were followed by dry seasons. Crops shriveled and died, men lost hope, homes had to be abandoned, towns were deserted, and whole cities were almost depopulated. The bitter lessons of these failures lasted for years, but now other settlers are buying up these abandoned farms and new methods are being tried. Practically every settler who has remained in the arid belt has been an experimenter in developing a kind of agriculture suited to the climate, and in some sections dry farming has become a success. It does not have the attraction or the security, however, of farming under irrigation.

For a number of years the Colorado Agricultural College made a systematic study of the efforts to grow crops without irrigation in the eastern part of the State. The results were summarized in station bulletins.[a] J. E. Payne, the observer, shows that in some years small grain produced large yields and large profits, and in other years failure was complete; that all attempts on adobe soils were failures; and that alfalfa on a dry farm can not endure the drain on its vitality, for while it flourishes in wet years it makes little growth in dry seasons, and the plants continue to die until they practically disappear.

Fruit growing without irrigation has not proven successful. Orchards may grow well for years, then an unusually severe drought kills them. The same is true of shade trees. As a result, nearly all settlers have been compelled to combine stock raising with farming, depending upon native grasses for summer pasturage and growing forage for winter feeding.

In a previous publication of this Department[b] Elwood Mead states that it is his conviction that dry farming in the semiarid belt must be supplemented by irrigation. He says:

> It is believed, however, that it is possible to control water enough to irrigate from 1 to 10 acres of each of thousands of farms where complete irrigation is not possible, and that this can be done by one of the three following plans:
>
> (1) Pumping from soil water or underground streams; (2) storage in small surface reservoirs of storm waters, or the irregular flow of streams; and (3) irrigation with flood water whenever it can be had, usually in the winter and spring, generally spoken of as winter irrigation.

[a] Colorado Sta. Buls. 59 and 77.

[b] U. S. Dept. Agr., Yearbook 1905, p. 430.

In many places water can be put on the land with lifts of 10 to 40 feet. In some places windmills are now pumping water for irrigation, and actually irrigating from one-fourth acre to 7 acres each. Next to pumping comes the small reservoir, which will catch enough storm water to irrigate a small tract. These can be constructed by placing a dam across a watercourse and catching the floods. The dam must be carefully constructed and ample spillway provided. Many favorable locations for this may be found. The last method is by damming the watercourse and causing the run-off to flood the land. By this method water is stored in the soil for the future use of plant life.

One irrigated acre on a dry farm will grow a windbreak of trees, which will serve as a shade in the summer and as a stock protection in the winter, and will grow a garden for the ranchman's use. If 5 acres are irrigated, and 1 acre given to trees and garden, 4 acres will be left for field crops. Planted to alfalfa it will produce 12 to 16 tons of hay, enough to support the farmer's milch cows and his horses.

The United States Department of Agriculture has agents searching the world over for drought-resistant plants and plants which grow with scant rainfall. Their efforts should bring to this vast region some plants of value. The farmers are also studying soils and their moisture-retaining qualities, and methods of conserving the moisture for future plant growth, and learning much of value.

The dry farm should have a larger acreage than either the irrigated or humid farm. The foundation of the dry farm should be mixed husbandry in which stock raising, with poultry and dairying, are the leading features. Enough land should be provided to furnish summer pasturage for stock, and as it takes 10 to 100 acres of native grass to support an animal, this summer pasture must of itself be larger than the cultivated farm in many sections. With live stock as a foundation, and with alfalfa, vegetables, and fruit grown by irrigation, the dry-farmed portion will insure large crops in wet years and render the farmer largely immune from losses in years of drought. Eventually, this region will support a large though somewhat scattered population. Some few favored sections, where the rainfall is opportune and the soil is fertile and has moisture-retaining qualities, are already well settled.

FARMING UNDER IRRIGATION.

The advantages of farming under irrigation as compared with farming in a humid climate are—

(1) Better opportunities are given to properly prepare the seed bed, as the rainfall is seldom sufficient to make the soil so wet that it can not be properly worked into a good tilth.

(2) A dry surface promotes a better and deeper root growth and thus produces a much more vigorous plant.

(3) Water can be applied at a time that will produce the largest yields.

(4) The opportunities for harvesting without injury from rains are better.

(5) The yields of a first-class article are better.

Estimates of the cost per acre of farming under irrigation are given below:

Cost per acre of raising various crops.

WHEAT.[a]

[Based on a yield of 40 bushels per acre.]

Plowing ground	$1.75
Preparation of seed bed	.75
Seed, 75 pounds, at 2 cents per pound	1.50
Seeding	.40
Irrigating	.60
Harvesting	1.00
Thrashing	1.75
Depreciation of machinery, etc	.50
Total	8.25

OATS OR BARLEY.[a]

[Based on a yield of 60 bushels per acre.]

Plowing ground	1.75
Preparation of seed bed	.75
Seed, 75 pounds, at 2 cents per pound	1.50
Seeding	.40
Irrigating	.60
Harvesting	1.00
Thrashing	1.80
Depreciation of machinery, etc	.50
Total	8.30

BEETS (NORTHERN COLORADO).[a]

[Based on a yield of 13.5 tons per acre.]

Plowing 8 inches deep	1.75
Preparing seed bed	1.50
Planting	.50
Seed, 20 pounds, at 15 cents per pound	3.00
Rolling	.25
Cultivating, four or five times	2.50
Bunching and thinning	7.00
Hoeing, two or three times	2.00
Plowing out beets	2.50
Three irrigations, at 60 cents each	1.80
Topping and piling	7.00
Siloing, 25 per cent of crop	1.20
Depreciation of machinery, etc	1.00
Hauling, not to exceed 3 miles	6.00
Total	38.00

[a] Estimate of W. H. Olin, professor of agronomy, State Agricultural College, Fort Collins, Colo.

BEETS (SOUTHERN COLORADO).[a]

[Based on a yield of 12 tons per acre. Average price at all Colorado factories, $5 per ton.]

Plowing 12 inches deep		$3.00
Three harrowings and levelings		2.00
Seed, 20 pounds	($2 to)	3.00
Planting		.40
Cultivating, five times		3.00
Rolling		.25
Bunching and thinning		7.00
Hoeing, twice		2.50
Three irrigations		1.80
Plowing out beets		2.50
Topping and piling		7.50
Siloing, one-fourth of crop		1.20
Hauling, within 3 miles		6.00
Depreciation of machinery, etc		1.00
Total		41.15

POTATOES (SAN LUIS VALLEY).[b]

[Based on a yield of 150 sacks per acre. Average price for ten years has been 75 cents per 100 pounds.]

Preparing ground	$3.50
Seed, 1,000 pounds, at 75 cents per 100 pounds	7.50
Planting	.75
Irrigating	1.00
Cultivating, three times	2.25
Digging	7.50
Sacks	9.00
Total	31.50

POTATOES (GREELEY DISTRICT).[c]

[Based on a yield of 100 sacks per acre. Average price for past ten years, 72.5 cents per 100 pounds.]

Plowing	$2.00
Harrowing	.50
Planting	1.50
Seed	9.00
Cultivating	1.50
Irrigating	1.50
Sacks	7.50
Harvesting	6.00
Marketing	4.00
Total	33.50

[a] Estimate of W. K. Winterhalter, consulting agriculturist, American Beet Sugar Company, Rockyford, Colo.

[b] Estimate of F. W. Beidler, Del Norte, Colo., secretary Del Norte Potato Growers' Association.

[c] Estimate of G. M. Houston, Greeley, Colo.

PEAS (SAN LUIS VALLEY).

[Based on a yield of 20 bushels per acre.]

Seeding on stubble ground	$0.35
Seed	1.00
Irrigating	.25
Harvesting and stacking	1.90
Thrashing	3.00
Total	6.50
Average yield, 20 bushels, at 75 cents per bushel	15.00
Profit	8.50

Many farmers fatten lambs and hogs by pasturing the peas and do not harvest the crop. The following seems to be a fair average of the amount of mutton or pork that an acre of peas may be expected to produce:

Mutton, 120 pounds, at 6.5 cents per pound	$7.80
Cost of growing crop without harvesting and thrashing	1.60
Profit per acre	6.20
Pork, 250 pounds, at 4.75 cents per pound	11.87
Cost of growing crop without harvesting and thrashing	1.60
Profit per acre	10.27

The practice of the lamb feeder is to buy his stock from the flock master in the early autumn at a less price per pound than he receives when the lamb is marketed, the additional flesh enabling the feeder to make 1.5 to 2 cents per pound on the original carcass, besides paying for the flesh put on. No estimate is made in the above to cover this item of profit. The hog raiser generally grows his own stock, and the profit given above for hogs will probably be very nearly equaled by those for lambs if proper allowance is made for the increased price of the mutton bought by the feeder.

ALFALFA.

Alfalfa does well in all parts of Colorado and there are upward of 449,000 acres grown in the State, most of which gives three cuttings a year. Following is an estimated cost of growing 1 acre of alfalfa for five years and the profits:

Cost of growing alfalfa.[a]

First year:	
Plowing	$1.25
Preparing seed bed	1.00
Seed, 15 pounds, at 15 cents per pound	2.25
Seeding	.50
Mowing and stacking, three crops, at $1.25 each	3.75
Cost of irrigating	.75
Total	9.50

[a] Estimates by W. H. Olin, professor of agronomy, Colorado Agricultural College.

Each following year:	
Harrowing	$0.25
Mowing and harvesting, three crops, at $1.25 each	3.75
Irrigating three times	.75
	4.75
Value of crop first year, two cuttings, 2 tons, at $5 per ton	10.00
Net profit	.50
Value each succeeding year, three cuttings, 4 tons, at $5 per ton	20.00
Cost of growing crop	4.75
Net profit per year	15.25
Net profit for five years	61.50

ROTATION OF CROPS.

The early agriculturist discovered that the continuous growing of any crop on the same ground exhausted the soil, but for some time was at a loss to discover a method of replenishing the elements taken up by plant growth. Fertilizers were expensive and scarce. It was found later that ground which has grown alfalfa for several years gave very large returns when seeded to grain, potatoes, or beets, and a method of crop rotation was evolved in which alfalfa was used as the fertilizing crop. Two systems of rotation are usually employed. They are the six-year rotation and the eight-year rotation. In the first system the order is: Alfalfa, three years; potatoes or sugar beets, two years; and oats or wheat, one year. Alfalfa seed is sown usually with wheat or oats in the sixth year, and in the seventh year the ground grows alfalfa.

In the eight-year rotation the order is: Alfalfa, three years; beets, one year; potatoes, one year; beets, one year; wheat, one year; oats, one year. Alfalfa is again sown with the oats.

EQUIPMENT AND CAPITAL REQUIRED FOR FRUIT GROWING.

While many successful and profitable fruit farms comprise 160 to 1,000 acres each, the best returns and the largest profits from land investments are, as a rule, obtained by farmers on small tracts.

In some districts irrigated peach and apple orchards have sold as high as $2,000 to $3,000 per acre, based upon the earning capacity of the orchards in these districts. Where such favorable conditions exist, the average size of the fruit farm is 5 to 10 acres, and in such districts the home seeker who desires to invest in a full-bearing fruit farm will find the question of capital and equipment a very simple one. He can buy a 10-acre orchard, with house, stable, and such tools as may be needed, at any price from $6,000 to $12,000, with not more than $500 additional to carry him through the first season until crop returns are in, after which all should be clear sailing, pro-

vided he has made no mistake in the selection of his location or as to varieties of fruit in the orchard. When the orchards are small, and there are a great many of them in the vicinity of a shipping point, the custom is to form a cooperative shipping association, which employs a competent marketing man as manager, builds packing sheds, storage cellars, and warehouses for handling and shipping the entire crop of its members. In some cases the packing is done at the headquarters and under the supervision of the association manager. This simplifies matters to a large extent, and requires a smaller outlay for the individual grower in the way of packing and storage buildings on the farm, besides insuring a uniform grade and pack of all fruit shipped by the association.

For the horticulturist who contemplates orchard fruit growing, the 40 or 80 acre farm can be developed with greatest economy, and will insure a larger income from the money invested. A large farm, one of the latter size, affords an opportunity for speculation, as one-half of the place, when it comes into bearing, can often be sold for enough to pay the entire cost of the 80 acres and all improvements. The cost per acre will not be less on a larger tract than on a place of 40 to 80 acres, but on a smaller tract it will be proportionately more. Consequently the estimate of the equipment and capital required has been based on a 40-acre farm.

Peach, cherry, plum, and prune trees come into full bearing in one-half to two-thirds the time required for apple trees, and therefore require a smaller investment. On the other hand, apple trees planted a greater distance apart give an opportunity for growing crops between the rows during the first three or four years.

As a general proposition, the ideal commercial orchard will cost $100 to $150 per acre above the first cost of the land and water rights to bring it to full fruiting age. After counting the interest on money invested from the time of purchase of the land to the first paying crop and allowing a reasonable amount for the risk in shipment, planting, and growing of the trees for three to eight years, the conclusion is reached that an orchard of producing size that can be bought for $300 an acre is a better investment than starting with the raw land and building a place.

In the estimate which follows, $100 per acre has been allowed for the raw land and the water right. In many places good fruit lands are obtainable for less money, but it pays to be sure of a good water supply, and lands with a water right such as can be depended upon at all times can hardly be bought for less than the price named. It is important also to select good land which is located not over 4 miles from a good shipping station. One to 2 miles is much better and adds $25 to $50 per acre to the value of an orchard.

Cost of establishing a 40-acre farm.[a]

FIRST YEAR.

40 acres with perpetual water right, at $100	$4,000.00	
House, five or six rooms	1,000.00	
Barn and outbuildings	500.00	
Fences	100.00	
Good team—mares or mules	250.00	
Riding and driving horse	75.00	
Milch cow	50.00	
Hogs and poultry	25.00	
1 set double work harness	30.00	
1 set single work harness for furrowing	10.00	
1 set single buggy harness	13.00	
Farm wagon	90.00	
Spring wagon or buggy	75.00	
1 common 12-inch walking plow	12.00	
1 Diamond 8-inch plow for work near trees	11.00	
1 single shovel furrowing plow	3.50	
2-section steel harrow	12.00	
Disk harrow or riding cultivator	30.00	
Single cultivator	7 50	
Pruning tools, shovels, hoes, etc	20.00	
		$6,314.00
Trees and plants:		
20 acres apples, 1,400 trees, at 10 cents each	140.00	
5 acres peaches, 700 trees, at 6 cents each	42.00	
2 acres cherries, 280 trees, at 20 cents each	56.00	
1 acre prunes, plums, apricots, 140 trees, at 20 cents each	28.00	
1 acre grapes, 900 vines, at 3 cents each	27.00	
1 acre raspberries and blackberries, 1,000 canes, at 1 cent each	10.00	
1 acre gooseberries and currants, 1,000 bushes, at 2 cents each	20.00	
1 acre strawberries, 10,000 plants, at $2.50 per 1,000	25.00	
5 acres alfalfa—seed for same	11.25	
3 acres garden and yards	10.00	
		369.25
Expense of operating first year:		
Plowing 40 acres, at $1.25 per acre	50.00	
Harrowing and dragging, at 50 cents per acre	20.00	
Furrowing ready to plant	20.00	
Planting 20 acres apple trees, at $3.50 per acre	70.00	
Planting 8 acres stone fruits, at $6 per acre	48.00	
Planting 1 acre grapes	10.00	
Planting 1 acre raspberries and blackberries	10.00	
Planting 1 acre gooseberries and currants	10.00	
Planting 1 acre strawberries	15.00	
Making head laterals	20.00	
Bridge, culverts, and head gates	40.00	
Cultivating 32 acres six times	96.00	
Hoeing 28 acres orchard twice	28.00	

[a] Estimate by J. H. Crowley, Rockyford, Colo.

Expense of operating first year—Continued.

Hoeing 4 acres berries, etc., three times	$24.00	
Furrowing 32 acres for irrigating, five times	64.00	
Irrigating 40 acres five times	100.00	
Water assessments, maintenance of canal, 50 cents per acre	20.00	
Taxes	25.00	
		$670.00
Total for first year		7,353.25

SECOND YEAR.

Trees for replanting, 10 per cent of cost for first year	34.80	
Replanting	30.00	
1 deep plowing, 28 acres, at $1.25 per acre	35.00	
Cultivation, 32 acres, six times	96.00	
Hoeing, 28 acres, two times	28.00	
Hoeing, 4 acres, three times	24.00	
Irrigating, 40 acres, five times	100.00	
Furrowing, 32 acres, five times	64.00	
Cleaning out laterals in spring	20.00	
Water assessments, maintenance canal	20.00	
Taxes	25.00	
Repairs, fences, bridges, and buildings	25.00	
Pruning lightly	32.00	
Total		533.80

THIRD YEAR.

Practically same as second year. (No charge for replanting, but a slight increase in expense of pruning and in general repairs)		533.80

FOURTH YEAR.

General running expenses same as third year	533.80	
Additional equipment because of apple and peach trees coming into bearing, as follows:		
Spray pump, nozzles, and hose	25.00	
Spray tank	25.00	
Trucks for spray outfit and for hauling fruit	75.00	
500 picking boxes, at 14 cents each	70.00	
Dozen picking buckets	3.50	
1 extra team	250.00	
1 set double harness	30.00	
Packing shed	200.00	
Total for fourth year		1,212.30
Cost for first year		7,353.25
Total for four years		9,633.15

The estimate of the first year's work has been figured on the basis of hiring all the work done. If the owner does nothing more than oversee the work, his living expenses for the time so occupied may be added; but assuming that he does much of the work himself, the saving of hired help will pay the living expenses of himself and family. Therefore, the estimate as given will include all expenses that could

be charged properly to the investment. Further, no special allowance has been made for horse feed, but the estimated cost of plowing, cultivating, and other operations covers these items in the early part of the season, while the 5 acres reserved for alfalfa and planting to oats with alfalfa the first year will give sufficient feed to carry the stock through the remainder of the year. Land between tree rows will help also to supply live stock and poultry with food and to pay for all contingencies likely to arise which have not been provided for in the table.

This is a conservative and practical working estimate of the cost of establishing a good irrigated fruit farm.

To give an accurate estimate of the returns that can be reasonably expected is a more difficult task. With such a selection of fruits as outlined, a fair sum should be realized each year after the first season. The 1 acre of strawberries should return $200 to $500 the second season. Raspberries and blackberries should give as good results the third year. Grapes, currants, and gooseberries should bring some money the third year, and full crops thereafter. The fourth season should find all stone fruits in bearing, and the total crop for the year will bring $1,000 to $2,500, according to the season, prices, and other factors. After the fifth year some returns may be expected from the apple orchard, and the annual output of the farm should average $2,500 to $6,000. With an annual average gross income of $4,000 the expense of boxes, spray materials, cultivation, irrigation, pruning, packing, and hauling the fruit to shipping stations may be counted at $2,000, leaving a net profit of $2,000, or 10 per cent interest on a valuation of $20,000, or $500 per acre.

Second estimate of cost and profits of orchard. [a]

10 acres, at $200 per acre	$2,000	
200 trees to the acre, at 15 cents each	300	
Plowing, and planting trees, at $7.50 per acre	75	
Cultivation, irrigation, pruning, etc., $100 per year for five years	500	
Compound interest on investment for five years, at 8 per cent	1,250	
Total		$4,125
The sixth and seventh years' crops will pay all expenses.		
The eighth year, at 50 cents a tree, will net	1,000	
The ninth year, at $1 a tree, will net	2,000	
The tenth year, at $2 a tree, will net	4,000	
Total for crop		7,000
Balance in favor of orchard outside of value of land		2,875
Value of land with 10-year-old orchard, $1,000 per acre		10,000
The clear total value on the investment of $4,125 being $12,875.		

[a] Estimate by Doctor Tickenor, Rifle, Colo.

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LIST OF PUBLICATIONS OF THE OFFICE OF EXPERIMENT STATIONS ON IRRIGATION—Continued.

SEPARATES—continued.

*Review of Irrigation Investigations for 1902. By Elwood Mead, Chief of Irrigation Investigations, Office of Experiment Stations. Pp. 359-385. (Reprint from Annual Report of Office of Experiment Stations for 1902.)

Review of Irrigation Investigations for 1903. By Elwood Mead, Chief of Irrigation Investigations, Office of Experiment Stations. Pp. 469-502. (Reprint from Annual Report of Office of Experiment Stations for 1903.)

Report of Irrigation and Drainage Investigations, 1904. By Elwood Mead, Chief. Pp. 425-472. (Reprint from Annual Report of Office of Experiment Stations for 1904.)

*Losses of Irrigation Water and Their Prevention. By R. P. Teele. Pp. 369-386. (Reprint from Annual Report of Office of Experiment Stations for 1907.)

Review of Ten Years of Irrigation Investigations. By R. P. Teele, Pp. ii, 355-405. (Reprint from Annual Report of Experiment Stations for 1908.)

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